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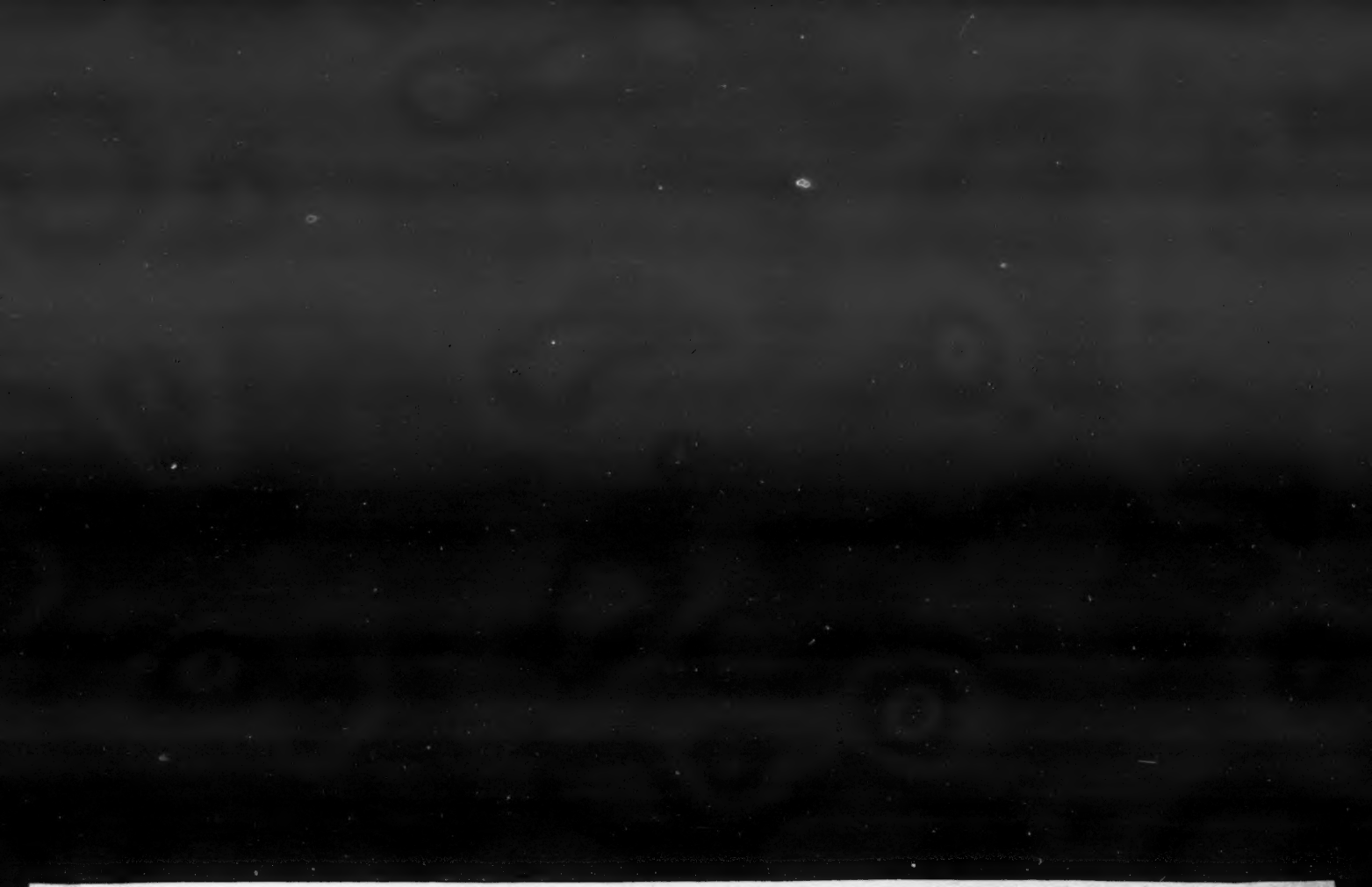


THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XLVII.—*On the Color Relations of Atoms, Ions and Molecules;* by M. CAREY LEA. Part II.

I. *Interaction of Ions.*

IF a colored substance be formed by the union of a colorless kation with a colorless anion, the color belongs to the molecule only. The colorless ions have so modified each others' vibration periods that selective absorption is exercised. As soon, therefore, as the molecule is divided into ions the color must disappear. Consequently if we find a solvent which, like water, is capable of separating the ions, the resulting solution when dilute must be colorless, no matter how intense the color of the compound.

The truth of this law of interaction has been tested experimentally in a considerable number of cases. The results, which were found to be without exception confirmatory, are given below.

Alkaline metals.—These form comparatively few colored products, soluble in water, by uniting with colorless atoms. Well marked instances are, however, found in the monosulphides.

Potassium sulphide, K_2S, is in the solid form cinnabar-red. It dissolves in water to a colorless solution.* The sodium salt acts similarly. As to the alkaline selenides and tellurides, their tendency to form poly-salts is so great that it is not possible to judge of the color shown by mono-salts in solution. It is of interest, however, that hydrogen selenide and probably also the

*Graham Otto, 5th Ger. ed., vol. iii, p. 240. The reactions here described have been either found or verified by the writer except in a few instances, and in these, as in the present case, the authority on which they are stated is given.

telluride are colorless; also the oxygen acids of both are colorless. There is little doubt, therefore, that selenium and tellurium, like sulphur, have colorless ions.

Mercuric iodide affords an excellent illustration of the principle stated owing to the large variety of solvents for it.

In hot ethylic alcohol it dissolves easily. Solution absolutely colorless, gives a cloud when poured into water which settles to a red powder.

Methylic alcohol acts similarly.

In solution of calcium chloride, especially if hot, dissolves easily. Less easily in barium chloride.

In solution of potassium and sodium chlorides dissolves sparingly. All these solutions are colorless.

In solutions of potassium bromide and of iodide it dissolves abundantly. Strong solutions have a yellowish color but become colorless by moderate dilution. These two salt solutions dissolve mercuric iodide freely in the cold; the other solvents need heat.

In cold solution of mercuric nitrate, it dissolves easily to a colorless solution. In solution of mercuric chloride it is somewhat soluble; the solution is colorless.

In glycerine it dissolves pretty well with the aid of heat and does not communicate a trace of color.

Mercuric arsenite is bluish gray. It is slightly soluble in solution of sodium arsenite. The solution is colorless.

Mercuric arsenate is pale yellow. It dissolves in a solution of mercuric nitrate and also in one of sodium pyrophosphate; both solutions are colorless.

The black heavy metallic sulphides are very difficult substances to bring into solution, but it seems that when this can be done the solution is colorless when the ions are colorless. This can be shown to be the case with mercuric sulphide and with antimony tri-sulphide. According to Weber,* when mercuric chloride is precipitated with an excess of ammonium sulphide the precipitate dissolves in potash to a colorless solution.

Silver oxid is slightly soluble in water. Being very deeply colored, it would seem natural that its solution should show this color. But the solution is absolutely colorless. This is because the silver ion is colorless. Metallic oxids having colored ions carry that color into their solutions, as is seen in the case of cupric oxid in alkaline solutions and in soluble forms of ferric oxid.

Silver arsenite is lemon yellow; it is abundantly soluble in ammonia water and in mercuric nitrate. Both solutions are colorless.

* Cf. Gmelin-Kraut, iv, page 851.

Silver arsenate.—Chocolate color; dissolves in the same solvents as the last and also gives colorless solutions.

Silver phosphate.—Triargentic phosphate dissolves with facility in nitric acid, in ammonia water and in mercuric nitrate. All three solutions are colorless.

*Cuprous sulphite.**—Red; dissolves in ammonia water and in dilute hydrochloric acid, giving colorless solutions.

Stannic sulphide precipitated.—Ochre yellow, dissolves in warm potash or soda solution; the resulting solution is nearly colorless.

It also dissolves in potassium sulpharsenite to a colorless solution.

Red antimony pentasulphide dissolves in alkaline monosulphides; solutions colorless.

Orpiment (As_2S_3) dissolves easily in warm potash or soda solutions; colorless.

II. *Combinations of Ions.*

Ions may combine. A. Two or more similar colorless ions may unite to form a colored elementary molecule.

The ions of iodine and bromine are colorless as shown in solutions of HBr and KBr, HI and KI. The molecules are strongly colored. The ions of lead are colorless, as shown in solutions of lead nitrate or acetate. The molecule (or the polymer) of lead is blue. The ion of sulphur is colorless—water is not colored when saturated with sulphydric acid. The oxygen acids of sulphur are colorless. But the molecule is yellow. Selenium has a colorless ion, but a strongly colored molecule. Colorless cuprous ions unite to form red copper.

B. Two or more similar ions, colored, may unite to form a colorless (or white) molecule or polymer. The ion of platinum is yellow in Pt^{iv}, red in Pt^{ii}; in each case the ions unite to form white platinum. The nickel ion is green; these unite to form white metallic nickel.

C. Two or more similar ions, colored, may unite to form a molecule of a wholly different color. Blue copper ions may unite to form red copper.

D. Two or more dissimilar colorless ions may unite to form a colored molecule. Sulphur and nitrogen unite to form orange-colored nitrogen sulphide. Sulphur and silver to form black silver sulphide.

It is an interesting fact, and one I believe that has not been previously noticed, that no ion and, therefore, no atom, is black, but is always transparent to some portion or portions of the visible rays. In this respect atoms and ions differ absolutely

* Gmelin Handbook, Ger. ed., iv, p. 622.

from molecules. For these last are often black, and this may be the case even with elements, as for example, iodine in the solid form, platinum black, etc. The absolute difference between atoms and molecules, the entire absence of color relation between them, was mentioned in the first part of this paper; it must always be one of the most remarkable facts in chemistry.

The production of a black molecule in no way depends upon the combination of two or more atoms having different relations to light, such that one should extinguish the rays which the other or others allow to pass. This might almost be expected, but is far from being the case. Two colorless atoms may unite to form a black molecule, as in the cases just mentioned.

It seems scarcely necessary to say that these remarks relate to inorganic molecules only. For in organic molecules, chemical composition has little influence, isomeric combinations exhibit the greatest differences, and their spectra show little relation to those of their elements.*

With organic compounds, which are formed almost exclusively of colorless atoms, it is always the color of the molecule that is important. With inorganic compounds the reverse is the case, we have much less to learn from the color of the molecule; that of the atom is all important. One and the same molecule may present various colors, absolutely unlike each other. Phosphorus and sulphur may be black, red or yellow. Gold is yellow by reflected, blue or green by transmitted light, and may be red when in a state of fine division. Who shall say in either case which of these colors is characteristic? With the ion, and therefore with the atom, at any given valency, there is no such ambiguity. Its color, its absorption spectrum, are invariable; these are always highly characteristic.

III. *Acid Indicators; Theory of their Reactions.*

Acid indicators are such as show a striking change by the addition of an alkaline solution, either from one color to another, or from a colorless to a strongly colored solution. They may be considered as of the nature of weak acids. Their reactions have been explained† in this way, that the radical has as an ion a color different from that which it has in the undissociated compound.

This explanation is unsatisfactory, for two reasons:

1st. It makes the color of an acid indicator in presence of an alkali depend on dissociation. But it can be shown that

* Ostwald, Lehrbuch, 2d Ger. ed., i, 472.
† Ibid, 800.

such a colored solution may be evaporated to dryness and thoroughly desiccated at 100° without losing anything of the intensity of its color. That is, the color persists under conditions in which dissociation is impossible.

2d. It makes the color or absence of color, as the case may be, of the solution of the acid indicator when isolated depend upon the absence of dissociation. But it is a familiar fact that by sufficient dilution even the weakest acids are largely or even completely dissociated.*

Let us take litmus for example. This is a weak acid red dyestuff which in contact with an alkali becomes blue. According to the explanation here criticized, isolated red litmus has a blue ion which does not appear in solution because not dissociated. But it is certain that with sufficient dilution it must be dissociated, and according to this explanation it should then turn blue. Whereas red litmus remains red with any amount of dilution so long as any trace of color is left.

Again it is said that blue litmus owes its blue color to dissociation. But the blue solution may be evaporated and desiccated at 100° without losing its blue color. The color is, therefore, *not due to dissociation*.

With these complex and faintly acid organic substances it seems probable that some change in their constitution takes place in the presence of an alkali, such that the anion that separates from the dilute solution of the isolated substance is not the same as that which separates from the alkaline combination. That is to say, the anion which separates from red litmus is not absolutely the same as that which separates from blue. Only in this way can the various reactions of acid indicators be satisfactorily explained. The reactions of these substances have not been studied with sufficient accuracy to indicate exactly what is the change that takes place in the presence of an alkali. It may be either a re-arrangement of some of the atoms or it may depend on the taking up of one or more molecules of water.

When an alcoholic solution of phenolphthaleine is dropped into much water, the resulting solution cannot be distinguished from pure water by its color. The addition of a trace of potash brings it to a deep rose red. Phenolphthaleine acts as a very weak acid; its very dilute solution must, therefore, be dissociated, and the colorless anion of the isolated substance must differ from the colored anion which separates from the potash compound. Also, a solution of the potash compound so dilute as to leave a transparent film, has been evaporated and then desiccated for many hours at 100°, the color of the solu-

* All their molecules become active, Ostwald, Lehrb., 2d G. ed., ii, 653; Nernst, Theoret. Ch., 440.

tion still fully remaining in the dry product. Now the potash compound of phenolphthaleine is known to be anhydrous. Anhydrous substances thoroughly desiccated cannot be in a dissociated state and, therefore, the rose red-color of the potash compound is not due to dissociation.

Further, if to the potash solution a solution of a silver salt is added there is formed a silver compound having the same constitution as that of the potassium compound. This silver compound is anhydrous and insoluble, nevertheless it has the same color as the potassium compound under conditions which make dissociation to be out of the question.

Paranitrophenol.—This is another acid indicator. In a solid state it is nearly colorless; it dissolves in warm water to a nearly colorless solution which on the addition of an alkali becomes gold-yellow. A portion of this solution evaporated so as to leave a thin film exhibits the same intensity of color as the solution, which color it retains after thorough desiccation. The color of the solution is, therefore, not due to dissociation. The solution of the substance itself when largely diluted gives no indication of the dissociation of a colored ion. The behavior of phenacetoline, another acid indicator, is analogous.

It seems, therefore, that dissociation has no essential connection with the reactions of acid indicators. It is simply that these substances by combining with alkalies either have their color much intensified or in some cases change it altogether.

Such changes are not in any way confined to acid indicators so-called. Picric acid in combining with alkalies has its color much intensified; the acid itself has a pale yellow color; the sodium salt (dry) has a pure deep yellow color. Chrysammic acid affords an example of a complete change of color; the acid itself is yellow, the potash salt a deep blood red, not only in solution but in the dry state so that its color cannot be due to dissociation. It may be remarked also that the potash salt in its dry state has remarkable optical properties which were investigated by Brewster, properties not possessed by the acid.

To the reactions which have been here examined might be added those of methyl orange, rosolic acid, and other acid indicators. I have found no exception to the rule that the characteristic colors exhibited by these substances when placed in contact with alkalies, are retained after a thorough desiccation. Also, no acid indicator when dissociated by a large dilution shows any tendency to exhibit an anion similar in color to that of its alkaline compound.

IV. *Classification, continued from Part I.**

Any attempted classification of the elements is necessarily subjected to a severe test through later discoveries. If the classification is in complete accordance with nature, it must offer suitable places for such new elements as may present themselves later. If it does not do this, it must be more or less artificial.

Mendeléef's remarkable predictions and the fact that the elements next discovered found places marked out for them in advance, caused his periodic law to be received with enthusiasm, It so happened that these new elements missed the weak portions of the system. This is now much changed. Within the last year or two, several new elements have been discovered for which the periodic law affords absolutely no place.

This appears to be admitted by Mendeléef. In an article† he contends that argon must be polymerized nitrogen and after examining the possible forms that nitrogen might take, he decides in favor of N_3.

But Berthelot succeeded in combining argon with carbon disulphide or with its elements, and from this compound he has been able to regenerate argon with all its characteristic properties. This Berthelot justly calls a capital fact. It is scarcely necessary to say that it is quite fatal to the theory of polymerization just mentioned.

The impossibility of finding a place for argon in the periodic system will become evident from the following considerations. If its atomic weight should prove to be 19·9 its place will necessarily be between fluorine and sodium. Introduced into the periodic system, it would take its place at the head of the iron group. It is to be remarked that in the periodic system the iron group is a somewhat singular one. It does not include any of the metals which we commonly associate with iron, cobalt and nickel, chromium and manganese. Instead of these, iron is made to form a group with ruthenium and osmium, so that if argon should enter in the periodic system with the atomic weight of 19·9 it would form the head of a group consisting of argon, iron, ruthenium and osmium. Or of one consisting of A, Co, Rh, and Ir. Or of another, equally anomalous, A, Ni, Pd, and Pt.

But argon may prove to have for its atomic weight the number 39·8. For such an element there is absolutely no place in

* In the first part of this paper (this Journal, May, 1895) in the table at page 362, by a vexatious mistake of the printer, the groups have been dislocated so that the series is no longer in numerical order, thus wholly destroying the sense of the table. On page 361 the order is correct and the table has been correctly printed in the German translation which appeared in the Zeitschrift für Anorg. Chemie.

† Reprinted in the Chemical News for July 12th, 1895.

any periodic system. The position required is already occupied by calcium and a place cannot be made without dislocating all the following groups, a strong argument in favor of the lower figure.

Helium with an atomic weight of probably 4 offers equally great difficulties. As the old periodic system excludes hydrogen and commences with lithium with an atomic weight of 7, any element having an atomic weight less than 7 is, like hydrogen, entirely outside of a system which does not recognize the existence of such elements.

In the system which I have proposed, helium, argon with the atomic weight of 19·9, and their congeners would constitute a group of their own, taking position between the hydrogen group and the lithium group.

In the first part of this paper I endeavored to show that the relations of atoms to the visual rays of the spectrum might be made the basis of a classification of the elements composed of these atoms and that such a classification harmonized extremely well with the known properties of the elements. Not that the particular color exhibited by an atom has for this purpose any importance; the question is simply whether color is present or absent. In other words, we have to inquire whether a given atom does or does not exercise selective absorption amongst the visual rays. It was there shown that the atoms of all the elements having atomic weights below 48 did not exhibit selective absorption. After these came two elements which I call transitional because at some valencies their atoms exhibit selective absorption and at others do not. Next, elements whose atoms at all valencies exhibit selective absorption. Next came a transitional element and then more elements having colorless atoms, and so on through the entire series of elements arranged in the numerical order of their atomic weights.

It is even probable that the distinction so established between these three classes of elements may eventually prove to have a far-reaching significance and that those elements whose atoms always exercise selective absorption may prove to be differently constituted in some important way from those whose atoms always allow free passage to all the visual rays.

About the same time that the first part of this paper appeared, Julius Thomsen proposed another and a different system of classification,* to which later he added a supplement† in reference to my paper with the object of showing that the elements which I had indicated as possessing colored ions were

* Zeits. fur Anor., Ch. ix, 192. † Ibid., x, 155.

found to come together and to occupy certain distinct positions in his series. This perhaps may be taken as additional proof of the conformity of the system which I have proposed to the essential characters of the elements.

A few weeks after the first part of this paper was read before the National Academy (April, 1895), M. Lecoq de Boisbaudran brought before the French Academy a note on the subject of the relations of the elements.* At page 1100 the elements to which his system of nodes and decrements applies, are tabulated. They are thirty-one in number, with three additional elements somewhat widely separated from the rest. I observe that all these thirty-one elements, without an exception, belong to my first division and have atoms that are colorless at all valencies. The three additional elements belong to the transitional class. The elements of the third division, that is, having atoms colored at all valencies, find no place in his classification. The chances are enormously against this happening fortuitously. The indications from both this and Thomsen's classification are, therefore, confirmatory of the principle I have endeavored to establish, that is, that the presence or absence of specific absorption of a certain range of rays is a function of the atomic weight and is closely related to the constitution of the elements.

In considering the theory of ionic dissociation it is necessary to bear in mind that no rigorous proof has ever been found for it. It remains, therefore, a theory only, a fascinating theory because it affords beautiful explanations of phenomena which otherwise have none.

There is, however, an important difficulty connected with this theory. The dissociated ions are often spoken of as "free ions," which in the absence of exterior electrical agencies, static or dynamic, they do not appear to be. It is certain that after dissociation the ions continue in some way to influence and control each other. This fact appears in a great number of reactions, of which the following familiar one may be taken as typical.

If to a dilute solution of ferrous chloride we add dilute hydrochloric acid in excess, completely excluding the air, there will be a considerable dissociation and the ferrous ions will be in presence of more than enough chlorine ions, *if these were free*, to cause at least some portion of the ferrous ions to acquire additional valency and become ferric ions. No change of the sort can be detected. The chlorine ions which would bring about this change are held in check by the hydrogen

* C. R., cxx, 20 (May 20th, 1895).

ions with which they were previously combined. That this is true is shown by removing the hydrogen ions, which is easily done by the addition of nitric acid. Thereupon those chlorine ions which were previously influenced by, and influenced, the hydrogen ions, now influence the ferrous ions, converting them to ferric ions.

The facts of osmosis seem to indicate that dissociated ions are mechanically free, inasmuch as the total number of molecules appears to be increased. But the above reaction, which is one of a great number, shows that in a chemical sense they cannot be considered as free.

Those who, like Ostwald, on the contrary hold that dissociated ions are perfectly free* would perhaps explain the above reaction by the asserted principle that plurivalent ions have a tendency to lose a portion of their valency.† One of the examples given (p. 796) is that of the trivalent iron ion, which by reason of its tendency to lose valency, may act as an oxidizing agent.

This reasoning does not seem to be sound. Whatever may be the tendency of the ferric ion to lose valency, the tendency of the ferrous ion to gain it is still stronger, so that ferrous chloride acts as a powerful reducing agent by reason of the strong tendency of the ferrous ion to acquire additional valency. This tendency of the ferrous ion shows itself in other ferrous salts and a similar tendency is exhibited by cuprous and stannous salts. In fact it may be said that most of our powerful reducing agents owe their activity to the tendency of ions to acquire additional valency; consequently it cannot be admitted that an opposite tendency prevails. And when in the above mentioned reaction we find that ferrous chloride in dilute solution with hydrochloric acid does not take up additional chlorine ions actually present in spite of its strong tendency that way, we are compelled to believe that the chlorine ions of the hydrochloric acid, though mechanically dissociated, are still held in check by, and hold in check, the hydrogen ions.

In this connection I may refer to some interesting remarks made by Professor Fitzgerald in his recent Helmholtz Memorial Lecture, reported in Nature (January 30, 1896).

"It is almost impossible to explain dynamically the assumption that free electrically-charged ions wander about in a liquid in a condition at all rightly described as one of dissociation."

And again:

* Lehrbuch, 2d Ger. ed., ii, 783.
† Ib., 796 and 801.

"The term dissociation as applied to electrolytes in which this independence of the ions does not exist is obviously a misnomer. There is said to be an electrical force acting between the various oppositely charged ions into which a dissolved molecule separates, which in some way binds them. Even in dilute solutions this force is very considerable and must make the condition of charged ions moving independently in the liquid so unstable as to be dynamically impossible unless other important forces operate at the same time."

From these various considerations the following conclusions may be drawn.

1. When highly colored inorganic substances are composed of colorless ions, then if these substances can be brought into solution as electrolytes, the color wholly disappears. A number of instances are given above and no exceptions were met with. Much that is important follows from this. It is proved that the ions have become so far separated that they no longer influence each others' vibration periods. For example, antimony pentasulphide is an intensely colored substance. It dissolves easily in solution of alkaline sulphides forming absolutely colorless solutions, because the ions of antimony and of sulphur are colorless and in the act of solution they separate sufficiently to no longer change each others' vibration periods, without however passing out of each others' sphere of influence. The ion theory is the only one capable of explaining this loss of color, and on the other hand the reactions are so exactly conformable to that theory that they constitute a new proof of its correctness: perhaps the best proof yet presented.

2. The union of ions colored and colorless gives rise to the most surprising changes of color. Two similar colored ions may unite to form a colorless element. Two similar colorless ions may unite to form a strongly colored element. No black ion is known. There is absolutely no relation traceable between the color of an ion and that of the element which it aids to form.

3. The change of color of an acid indicator placed in contact with an alkali in no way depends upon dissociation. Dissociation may result, but the change of color is independent of it.

4. Selective absorption of the visual rays by an element can never constitute a basis for classification, but the relation of ions to the visual rays leads to a classification which is in absolute harmony with the chemical characteristics of the elements. Quite recently two chemists, Thomsen and deBoisbaudran, have proposed new systems of classification, in both of which

it appeared subsequently that the elements having colorless ions had come together. And in Thomsen's system the same was also true of the elements having colored ions.

5. While there is good reason for believing that in solution the ions are separated so as to no longer affect each others' vibrations (see sec. 1, supra), it is also certain that they remain within each others' range of influence, so that they cannot be considered as free. Fitzgerald has shown that this conclusion is in conformity with theory and experimental evidence has been given above, proving that it is also in conformity with fact.

Art. XLVIII.—*The Gravimetric Determination of Selenium;* by A. W. Peirce.

[Contributions from the Kent Chemical Laboratory of Yale College.—L.]

The method generally in use for the gravimetric determination of selenious acid is to precipitate the selenium with sulphurous acid in presence of hydrochloric acid and to weigh the elementary selenium. Precipitation by this method, however, is slow and incomplete in many cases, so that it is always necessary to treat the filtrate a second time with sulphurous acid and to digest for some time. To obviate the necessary delay in this process, I have tried the effect of substituting potassium iodide as the reducer instead of the sulphurous acid, adopting the idea from several recent volumetric methods for the determination of selenium* in which an iodide in acid solution is used to reduce the selenious acid, and in which the liberated iodine, caught in various ways, is titrated and taken as a measure of the selenium.

Varying amounts of selenium dioxide prepared according to the method described in former articles, by dissolving pure selenium in nitric acid, removing any selenic acid formed by barium hydroxide, and subliming in a current of dry oxygen, were dissolved in Erlenmeyer flasks, and the solution was acidified with hydrochloric acid. Potassium iodide was added and the selenium was precipitated in the form of a red powder. Boiling for ten minutes served to remove most of the liberated iodine and to change the selenium into the black modification, which was collected upon an asbestos felt, washed, dried at 100° to a constant weight, and weighed. Early experiments

* Muthman and Schaefer, Ber. d. d. chem. Gesell., xxvi, 1008; Gooch and Reynolds, this Jour., l, 254; Gooch and Peirce, this Jour., fourth series, i, 31.

showed that for small amounts the process gave accurate results, but that for large amounts the errors came far too high:

	Se taken grm.	Se found grm.	KI grm.	Volume cm³	Error grm.
(1)	0·0355	0·0356	1	100	0·0001 +
(2)	0·0355	0·0355	1	"	0·0000
(3)	0·0355	0·0356	1	"	0·0001 +
(4)	0·2968	0·3883	4	75	0·0915 +
(5)	0·2033	0·2475	4	100	0·0442 +
(6)	0·3058	0·3495	10	100	0·0437 +

When the selenium amounted to less than a tenth of a gram the results came out well. When the amount was larger the selenium assumed on boiling a pasty molten condition which made filtering and washing impossible. This condition was observed in the work already referred to, and the mass seemed to consist of selenium with included iodine, as it gave up iodine slowly to water on standing and more rapidly to a solution of potassium iodide.

It has been found in the work to be described that if an excess of potassium iodide be used considerably above the amount necessary for precipitation, the pasty condition of the selenium does not occur, the iodine evidently being held in solution by the excess of the potassium iodide. This would seem to indicate the total release of the iodine, and would make possible the determination of quantities larger than the two-tenths of a gram set in the former work as a limit for the range of the process. Several determinations, which resulted very satisfactorily, were made according to the volumetric method thus modified, and at the same time the selenium which was precipitated was weighed. By the former method, in which the iodine evolved was estimated, the results were too low, and by the latter method, in which the residue was weighed, too high; but there appeared to be no definite relation between the errors of the two processes, as there would be if the retention of iodine were the only difficulty. Digestion of the selenium in the crucible with hot water removed a small amount of potassium iodide and reduced the error considerably; so that it was apparent that the increase in weight was due to the fact that the precipitated selenium included potassium iodide from the concentrated solution.

	SeO_2 taken grm.	SeO_2 found grm.	KI grm.	Volume cm³	Error grm.	Se taken as SeO_2 grm.	Se found grm.	Error grm.
(7)	0·4870	0·4868	7	60	0·0002—	0·3467	0·3507	0·0040 +
(8)	0·4980	0·4971	10	"	0·0009—	0·3545	0·3575	0·0030 +
(9)	0·7323	0·7310	10	75	0·0013—	0·5214	0·5312	0·0098 +

Later experiments under similar conditions, excepting that the volume of the liquid in which the precipitation took place was very much increased, so that the tendency on the part of the selenium to include the iodide might be diminished, gave errors entirely within satisfactory limits though always positive.

	Se, taken as SeO_2 grm.	Se found grm.	KI grm.	Volume cm^3.	Error grm.
(10)	0·2853	0·2861	7	900	0·0008+
(11)	0·3189	0·3192	8	400	0·0003+
(12)	0·3318	0·3324	7	500	0·0006+
(13)	0·3798	0·3805	7	500	0·0007+
(14)	0·4252	0·4259	7	350	0·0007+
(15)	0·4430	0·4434	10	450	0·0004+

It is sufficient to dilute to 400 cm^3 before acidifying with hydrochloric acid and adding potassium iodide to an amount about three grams in excess of that actually required. Boiling for 10 to 20 minutes will change the selenium to the black modification and remove most of the iodine. The process of precipitation and filtering can be completed in half an hour. The selenium is dried at 100° to a constant weight.

When the selenium occurs in the higher form of oxidation the reduction follows the same course, though iodine is not liberated until the solution is quite warm; but at the end of the usual time of boiling the action is complete. The following shows the results obtained by acting in the manner described on selenic acid.

SeO_2 taken grm.	Se taken grm.	Se found grm.	KI grm.	Volume cm^3.	Error. grm.
0·1709	0·1063	0·1065	5	500	0·0002+
0·1709	0·1063	0·1062	5	375	0·0001—
0·3231	0·2010	0·2017	5	350	0·0007+
0·5005	0·3115	0·3126	6	500	0·0011+

Evidently this method will not distinguish between selenious and selenic acids, but it will be found of much value in point of time saved in the determination of either separately, or of the total selenium in case both occur together.

The kindly advice and suggestions of Prof. F. A. Gooch are gratefully acknowledged.

ART. XLIX.—*The Extinct Felidæ of North America;* by GEO. I. ADAMS, Fellow of Princeton College. (With Plates X, XI, XII.)

THE following paper is a result of studies by the author in the Department of Palæontology of Princeton. It is an attempt to summarize the literature on the extinct Felidæ, to add such new points of knowledge as it has been possible to discover and to propose a classification for the family. I wish here to express my thanks for privileges of study kindly extended by Prof. H. F. Osborn and Dr. J. L. Wortman of the American Museum, to Prof. Cope for suggestions and use of material, and to Mr. Dixon and Dr. Nolan of the Philadelphia Academy for assistance in examining specimens and literature in that institution. I wish also to acknowledge my special indebtedness to Prof. W. B. Scott, whose valuable criticism and kindly interest have been an inspiration to me in my work, and to Mr. J. B. Hatcher, from whom I have received much information and assistance. The illustrations are by Mr. Rudolph Weber and their excellence is due to his care and skill.

Osteology of Hoplophoneus Primævus.

Hoplophoneus primævus is at present known from a short description of the type skull by Leidy (Geol. Sur. Wis., Iowa, Minn. and Neb. 1852), and later from a description of a specimen nearly agreeing with the type along with a second larger skull which belongs to a different species (Extinct Fauna of Dak. and Neb.) A restoration and brief description has been published by Scott (Bull. Mus. Comp. Zoology, Harvard, 1887). The material here described consists of a nearly complete skeleton, which is well preserved (No. 10741, Princeton Collection) and a skull somewhat crushed (No. 11013). In addition there is in the same collection a skeleton (No. 10934) not very complete but having associated with it the anterior and posterior portions of the skull which agree very closely with the above mentioned specimen and is supplemented by another lacking the occiput (No. 10540.) This latter specimen is slightly smaller but is a young skull just losing the deciduous canines. The principal material is that which was referred by the writer to *H. primævus* in the American Naturalist for January, '96, and corresponds with the original type.

This species of *Hoplophoneus* is of special interest inasmuch as it agrees very closely in size with *Dinictis felina*, the osteology of which is known from the description by Dr.

Scott (Proc. Phila. Acad., 1889). In describing it I shall make comparisons with the lynx (*Lynx canadensis*) and occasionally with the lion, since the bones of the lynx, although they are nearly the same size, do not express the feline characters so well as do those of the lion. I shall not attempt to quote from previous descriptions or give minute descriptions where the characters agree with those of recent felines. The osteology is illustrated by Plate X.

In general *Hoplophoneus primævus* is comparable in size with the lynx, although having a longer head, the distal portions of the limbs relatively much shorter and the tail long.

The skull.—The skull is one-fourth longer from the condyles to the premaxillary border than that of the lynx. This is due to a greater proportionate length of the face and palate. In *H. primævus* the distance from the condyles to the line of the upper molars is nearly the same as from that line to the premaxillary border. While in the lynx the first measurement is about the same as that of *H. primævus*, the latter is only about one-half as great. The brain case is not quite so large as that of the lynx and the post-orbital constriction is much more marked. The face is not only proportionately longer but wider, the width at the canines being as great as the width of the brain case at the parieto-temporal suture. The zygomata are expanded about as much as in the lynx in proportion to the length of the skull, but the space enclosed is proportionately longer and much wider because of the constriction of the brain case and the smaller size of the orbit. The orbit is considerably smaller than that of the lynx and is horizontally oval. The post orbital processes of the frontals and malar are short and rather stout.

The face is strongly arched transversely; seen from the side the angle it makes with the posterior portion of the skull is about the same as in the panther or lion, but it is straighter and the frontal region not so full.

The bones of the skull are much thicker than those of the lynx and the processes and borders much more massive. This is seen in the inion and post-tympanic process. The latter is trihedral and truncated distally. It is directed slightly towards the post-glenoid as if tending to approach it. The zygomatic process is strong and drooping with its glenoid portion looking slightly inward. The lambdoidal and sagittal crests are rather high and thick. The fronto-temporal ridges diverge at the fronto-parietal suture.

The sutures of the skull are very similar to those of recent felines. The nasal processes of the frontals do not extend so far anteriorly, being separated by a considerable space from the ascending rami of the premaxillaries. The nasals are long

and inserted well into the anterior border of the frontals, their posterior borders being broadly rounded. The bullæ are seldom preserved, but judging from a cast of one they are moderately expanded.

The foramina of the skull present peculiarly primitive characters, as has already been recognized. The condylar and carotid are distinct from the foramen lacerum posterius. There is a post glenoid foramen. The foramen ovale enters the outer end of a deep transverse groove situated in the base of the zygomatic process. There is an ali-sphenoid canal, the posterior opening of which is in the inner portion of the above mentioned groove and its anterior opening is just back of the anterior lacerated foramen. The opening of the foramen rotundum is concealed within the alisphenoid canal. The optic foramen is in the same relation to the anterior lacerated as in the cats. There is also an ethmoidal foramen present. The palatal foramina need no special description. There is a post-parietal foramen and sometimes two. The infra-orbital is large and vertically oval.

The mandible.—The mandible is quite characteristic of the Machærodonts. Its anterior portion consists of two vertical nearly plane surfaces meeting at a wide angle at the symphysis. The lateral face of the mandible is separated from the anterior by nearly a right angle marked by a distinct ridge, posterior to which is a shallow fossa for the superior canine. At this place the lower border of the mandible is produced into a moderate flange on the surface of which the fossa is continued. The symphysis is lower than the ramus and abuts against the flange on its inner side. The ramus is long and quite straight, being heaviest at the sectorial. The condyle is on a line with the alveolar border and is semi-conical. The coronoid is small and evenly rounded. The masseteric fossa is deep, the angle being well out from the plane of the coronoid. The dental and mental foramina are as in the modern cats. On the anterior or symphysial surface there are two foramina on either ramus.

Dentition.—There are three stout subconical incisors which are slightly recurved and are placed in nearly a semicircle. Their posterior surface, which is a little over one-third the circumference of the tooth, is slightly flattened and separated from the anterior by a sharp line which is slightly denticulate in an unworn tooth. They increase in size outward, the external being largest. The superior canines are long, compressed and slightly recurved. They are implanted by a strong fang which reaches well up to the frontal bone. Their anterior and posterior cutting borders are denticulate. When the mouth is closed the canines rest in the fossæ of the mandible, extending nearly as low as the flange. There is a small space

anterior to the canine and one about twice as great posterior to it. There are three superior premolars; the anterior one (p^2) is considerably the smallest and may lack distinct anterior and posterior cusps. The second (p^3) is well developed but may not have a distinct anterior cusp. The third (p^4) is the sectorial. This tooth is different from that of the lynx or lion in not possessing an internal cusp; the inner root, however, supports a convex buttress which descends from the principal cusp. There is also an anterior basal cusp which is rather incipient and situated high on the principal cusp. The posterior cusp is a long cutting heel. The upper molar is rather better developed than in the modern cats and is inserted as in the lion by two roots in a transverse line. The incisors of the lower jaw along with the canines form a regularly curved series, the canines being not much larger than the external incisors. The internal incisors are much compressed and in some specimens are hardly more than rudiments. They are slightly divergent and have the same general structure as the upper ones. The canine is curved slightly backward and has a rather stronger posterior border. Its greatest diameter is nearly in an antero-posterior line. It is also denticulate when unworn, but the border soon becomes smooth. Back of the canine there is a diastema about twice as great as in the upper jaw. There are two well developed premolars, the anterior being, however, considerably the smaller. The inferior molar is a sectorial and differs from that of the modern cats in having a low heel and a somewhat variable postero-internal cusp. The teeth of the molar series differ from those of the modern cats in being more compressed and in having sharper borders which when unworn are feebly crenulated.

The vertebræ.—There are sixteen presacral vertebræ of one specimen, all of which are considerably mutilated so that it is possible to judge only of the relative size and length of the centra. They indicate a much stronger vertebral column than that of the lynx and one which is proportionately shorter in the lumbar region. Five lumbar vertebræ measure considerably less than any five of same region of the lynx. On the other hand, the cervicals are longer than those of the lynx and the axis particularly so. The thoracic vertebræ are, as near as can be judged from comparison with those at hand, a little longer and, proportionately to the other vertebræ, also more massive. From what I know of other representatives of the genus I think it safe to say that the processes were stout and well developed. The sacrum, as would be expected, is heavier and wider than that of the lynx and its centrum is not so much depressed. The caudals are not preserved in the specimens of this species, but from the other species it is evident that the tail was long like that of the recent cats.

The pelvis.—I have only fragments of the pelvis, but they give an idea of its relative size and strength. The acetabulum is one-fifth greater in diameter than that of the lynx. As a whole the pelvis is more massive and considerably longer. At the sciatic notch, however, the ischium has about the same diameter as that of the lynx.

The scapula.—The distal portion of the scapula is considerably larger than in the lynx, the glenoid cavity being about one-fifth larger. There is a short stout coracoid much the same as in the modern cats. No other features are preserved in the specimens which are at hand.

The fore-limb.—The humerus of *H. primævus* is the same length as that of the lynx, but fully one-half more massive. The head presents a large articular surface which is very similar in shape to that of the cats. The great tuberosity is particularly prominent and rises considerably above the head and is well set off from it. The smaller tuberosity is low but rugose and the bicipital groove quite broad. The prominent character of the bone is the bold deltoid ridge which has a straight sharp border on the internal side extending to the great tuberosity.

On the outer side, the lower portion has a similar border which runs slightly divergent from the inner border, but farther up curves toward the smaller tuberosity and becomes a mere line on the convex surface. The prominence of the deltoid ridge makes the antero-posterior diameter of the humerus at its middle portion twice as great as the lateral diameter, a feature which is not met with in the Felidæ even in the lion. Below the deltoid ridge the anterior surface retreats rapidly as it descends, becoming an even convex surface. The supinator ridge is also very bold and is in fact a thin prominent border as far up as the lower portion of the deltoid ridge. Above it, extending in the same line but not connected with it, is a line for muscular attachment, extending to the base of the head. The ent-epi-condylar foramen is large and formed by a free arch, being but slightly depressed into the body of the bone. The trochlea is very similar to that of the lynx but slightly more oblique. The anconeal fossa is deep and large, but not perforated.

The ulna is practically of the same length as the humerus. Its olecranon is proportionately much longer than in the lynx and lion, being one-fifth the entire length, while in the lynx it is not quite one-eighth, and in the lion a little over one-seventh. The sigmoid cavity is long and defined much as in the cats. Except as to proportions, the ulna presents no especial peculiarities.

The radius is three-fourths the length of the humerus and is a short bone compared with that of the modern cats. Its head presents a distinct notch on the dorsal margin. The bone has sharp lines and the lower portion is quite rugose. The styloid portion is heavy and the process short. The scapho-lunar articular surface is rather smaller than would be expected.

The manus.—The manus is particularly short and the digits divergent. The scapho-lunar, although not much different from that of the lynx in general structure, is wider and has a better developed tubercle. The line of union of its two elements is visible on its distal surface in the facet for the magnum. The pyramidal is very seldom preserved with a specimen, but is fortunately retained in this case. It presents a concave surface for articulation with the unciform. On its external surface are two facets, the proximal for the pisiform and the other for the styloid process of the ulna. It also articulates slightly with the fifth metacarpal. The pisiform is well developed, articulating as in the Felidæ with the pyramidal and ulna. The unciform and magnum need no special description. In the specimen which I have the trapezium and trapezoid are absent. They are present in specimens of *Hoplophoneus insolens*. The trapezoid in them nearly excludes the second metacarpal from lateral contact with the magnum. In the specimen which I am describing the relation of the metacarpals is such as to indicate the same position. In this respect the carpus differs from that of the modern cats, in the lion the articulation being very large. The metacarpals are surprisingly short, being only about two-thirds as long as those of the lynx. The first metacarpal is about as much reduced as in the lynx or lion. The phalanges are large and the unguals have well developed hoods which are usually preserved.

The hind-limb.—The femur is the same in length as that of the lynx, but of course much heavier, and its extremities are rather larger in proportion to the strength of the shaft. The head is presented slightly more inward and forward. It presents about the same relative articular surface as the lynx and has a deep pit for the round ligament. The great trochanter is separated from the head by a more distinct notch, which is deepest at the neck. The digital fossa is deep and the posterior border of the great trochanter is reflected over it fully as much as in the lynx. The second trochanter is very prominent and its position is quite different from what it is in the modern cats. It is relatively farther below the head and not as much removed from the inner border of the femur. When the bone is viewed directly from in front a considerable portion of it is seen, while in the recent cats it is concealed by the shaft. The femur also differs from that of the recent cats in having a

distinct third trochanter which is connected above by a ridge with the great trochanter and is continuous below with the linea aspera externa. The shaft is more rugose than in the lynx and is not quite as straight. The patellar surface is broad and shallow and the condyles large.

The tibia is absolutely and relatively shorter than in the lynx, being not quite four-fifths as long as the femur, while in the lynx they are of the same length. In the lion the tibia is five-sixths the length of the femur. The condylar surfaces are large and are separated only by a low spine. The shaft of the tibia is compressed laterally and the cnemial crest is high. The anterior tuberosity is rather far from the condyles. The distal portion is quite different from that of the lynx or lion, inasmuch as the articular surface is very oblique and the astragalar groove only slightly indicated. The malleolus is heavy and straight. A distinct ridge rises on its anterior surface and extends a short distance up the shaft.

The fibula needs no special description. It is quite stout and has sharp lines for muscular attachment and is free the whole length of the shaft. Its distal end presents a large articular surface for the calcaneum.

The pes.—The calcaneum is slightly shorter than that of the lynx owing to its tubercle being not quite so long. The sustentacular portion is situated rather farther distally and the facet is presented more nearly upward. There is no facet to support the head of the astragalus as in the lynx. This last mentioned bone extends much farther distally than in the lynx although the neck is not proportionately longer. The astragalus of *Hoplophoneus* is larger, particularly the body portion. Its trochlear surface is only slightly grooved and its outer border very oblique. It is in these two respects very primitive. The cuboid is somewhat larger than that of the lynx, while the navicular is considerably wider and the tubercle not so much reflected upon the head of the astragalus. Its distal surface presents three distinct facets for the cuneiforms. In these bones the relationship as regards the articulation with the metatarsals is similar to that of the trapezoid and magnum in the manus, the second metatarsal being nearly excluded from any lateral articulation with the ectocuneiform. In the modern cats this wedging in of the second metatarsal is a very great element of strength. The ento-cuneiform is not so much reduced as in the lynx since the first metatarsal is not so rudimental. The length of the metatarsals is proportionately even shorter than the metacarpals, being only four-sevenths as long as those of the lynx. The first digit is not much reduced and carries an ungual.

Summary.

H. primævus differs from the recent Felidæ and the lynx in particular, in the following points:

The skull is Machærodont, is large in proportion to the body and long anteriorly.

The brain case is relatively much less expanded and the post orbital constriction is very marked.

The mandible has a distinct vertical anterior face and a moderate flange.

The post-tympanic is large, sub-cylindrical and shows a tendency to approach the post-glenoid process. The zygomatic processes are drooping.

There are distinct carotid, condyloid, post-glenoid and post-parietal foramina and an alisphenoid canal.

The dentition is $I\frac{3}{3}C\frac{1}{1}Pm\frac{3}{3}M\frac{1}{1}$. The superior canine is very long, recurved, compressed and when the mouth is closed extends nearly as low as the flange of the mandible, resting in a slight fossa. The superior sectorial has an anterior basal cusp but no internal, the internal root supporting instead a convex buttress which descends from the principal cusp. The inferior sectorial has a small postero-internal cusp and a low heel. The incisors are subconical and slightly divergent. The inferior canine is not much larger than the external incisor. All the teeth when unworn are denticulated or feebly crenulated and the superior canines are permanently so.

The skeleton is about the size of the lynx but more massive as in the lion. The cervical region is rather long and the lumbar short as compared with the lynx. The tail is long as in the lion.

The humerus has a strong massive deltoid ridge, the femur a third trochanter.

The ulna and radius and the tibia are proportionately much shorter than in the recent Felidæ.

The pes and manus are very short and broad. The astragalus is only slightly grooved and its tibial surface is oblique. The scapho-lunar shows the line of union of its two elements. The second metacarpal is nearly excluded from lateral articulation with the magnum and the second metatarsal from lateral articulation with the ecto-cuneiform.

The unguals have heavy hoods and were retractile.

The position of the feet was as in the modern cats.

A comparison with Dinictis felina.

The osteology of this species of *Dinictis*, as has already been stated, has been described by Scott. In addition to the material

which was known at that time, the Princeton Museum contains besides duplicate portions of the skeleton, a humerus and a few bones of the carpus. These need no special description for my purpose here. The genus *Dinictis* stands ancestral to the genus *Hoplophoneus* and the species *felina* agreeing so closely in size with *H. primævus* makes a comparison very interesting. I shall state here the points in which *D. felina* differs, although many minor points which would be apparent to the eye are necessarily omitted.

The skull is slightly larger and is higher in the frontal region.

The mandible has a smaller flange.

The glenoid process is not so low and the post-tympanic does not show a tendency to approach the post glenoid.

The dentition is $I\frac{3}{3}C\frac{1}{1}Pm\frac{3}{3}M\frac{1}{2}$. The incisors are small, spatulate and in an even transverse row. The outer one is considerably larger than the others. The canine is larger at the base and not quite so long. The superior sectorial has an inner cusp but no anterior basal. The inferior sectorial has a better developed heel. The second lower molar is much reduced but constant.

The foramina are the same.

The skeleton is of nearly the same size but not so massive.

The limb bones have more slender shafts and not quite so large extremities.

The ulna and radius and the tibia are not so short in proportion to the lengths of the humerus and femur, which are almost identical in length with those of *H. primævus*.

The manus and pes are narrower and longer.

The unguals have weak hoods but were retractile, although perhaps not perfectly so.

The generic distinctions are to be found in the structure of the sectorials, the character of the incisors and the unguals, although in distinguishing the two the other points above mentioned can be relied upon.

Measurements.

	H. primævus.	D. felina.
Length of skull condyles to premaxillary border	148	154^{mm}
Length of cranium to anterior rim of orbit	99	108
Length of bony palate	79	72
Breadth of bony palate at sectorials	61	69
Breadth of skull at canines	47	50
Breadth of skull at post-orbital constriction,	35	33
Length of mandible from condyle to lateral incisor	112	119

	H. primævus.	D. felina.
Length of humerus	160	172
ulna	163	---
radius	122	---
femur	185	190
tibia	143	168
calcaneum	43	43
metatarsal IV	37	53
metacarpal IV	38	--

The Hoplophoneus Series.

Hoplophoneus primævus Leidy and Owen.

This species was the first Machærodont found in North America and was described as *Machærodus primævus* and later as *Drepanodon primævus.* The establishment of the genus *Hoplophoneus* Cope, removed it to that group. In Leidy's description in the Ancient Fauna of Dakota and Nebraska a skull is referred to this species which is considerably larger than the original type and quite different from it. The species as here used is as limited by the writer in the American Naturalist, January, 1896. The description of the osteology preceding this makes further mention of it here unnecessary. Dental formula $I\frac{3}{3}C\frac{1}{1}Pm\frac{3}{3}M\frac{1}{1}$.

Hoplophoneus robustus Adams.

This species was proposed as representative of the larger skull, which was referred by Leidy to *H. primævus.* As compared with that species, it shows an increase in size and the skeleton is more massive. The skull is relatively large and the first superior premolar (pm^3) more reduced and in old specimens may be absent. To this species should be referred the specimen determined by Osborn and Wortman as *H. primævus* (Bull. Amer. Mus., 1894, p. 228). The figure of the skull and the measurements here given are from that specimen. $I\frac{3}{3}C\frac{1}{1}Pm\frac{2-3}{3}M\frac{1}{1}$.

Length of skull, condyles to premaxillary border,	180^{mm}
" humerus	170
" ulna	163
" femur	195
" tibia	160

Hoplophoneus occidentalis Leidy.

This is the largest species of the series. It was first proposed by Leidy on a fragment of a mandible (Extinct Fauna of Dakota and Nebraska). It is best known from a fine skull and nearly complete skeleton described by Williston (Kansas University Quarterly, June, '95), as *Dinotomius atrox,* which name, as has been shown by the writer, is a synonym (Amer. Nat., January, '96). The dentition is $I\frac{3}{3}C\frac{1}{1}Pm\frac{3}{3}M\frac{1}{1}$. The inferior sectorial is very strong and thick at the base, the postero-internal cusp is wanting and the heel is reduced.

Length of the skull, inion to premaxillary border, 260mm
" humerus 240
" tibia 237

Hoplophoneus insolens Adams.

The determination of the skeletal characters of *H. occidentalis* made it apparent that the specimen determined as such by Osborn and Wortman (Bull. Amer. Mus., 1894) is a quite distinct species, and it together with material in the Princeton collection was the basis of this species intermediate between *H. robustus* and *H. occidentalis*. As compared with *H. robustus* the skeleton is much larger, the limb bones being longer but not much heavier, the extremities being relatively smaller. The dental formula is $I\frac{3}{3}C\frac{1}{1}Pm\frac{3}{2}M\frac{1}{1}$.

Length of skull, condyles to premaxillary border, 190mm
" humerus 200
" ulna 212
" femur 250
" tibia 188

Hoplophoneus oreodontis Cope.

This species is the type of the genus. It was first described by Cope under the genus *Machærodus*, but better material enabled him to separate from that genus. The specimen figured in the series is interesting as supplementing the material already known. This skull (number 10515 in the Princeton collection) differs from that described by Cope in showing the roots of a much reduced pm^3, thus changing the dental formula of the species $I\frac{3}{3}C\frac{1}{1}Pm\frac{2-3}{2}M\frac{1}{1}$. It is the smallest species known from the White River.

Length of skull, condyles to premaxillary border, 135mm

Hoplophoneus cerebralis Cope.

This is the smallest species and the most peculiar. It is the only representative of the genus thus far found in the John Day. It is peculiar in showing a short temporal space, a very convex profile, and a nearly vertical and abrupt occiput. The superior sectorial has a better developed anterior basal cusp than the other species; in this respect it approaches *Machærodus*, as has been noted by Cope. Dentition $I^3/C^1/Pm^2M^1/$. The species is known only from a skull.

Length of skull, condyles to premaxillary border, 120mm

There are thus six species of *Hoplophoneus* disregarding, *H. strigidens* Cope, which being known only from a fragment of a canine which presents an unusual form, is not characterized by any features which refer it to that genus rather than any other. The series of skulls figured in Plate XI show a great variation in size and a study of the skeletons shows a like variation.

The Dinictis Series.

Dinictis felina Leidy.

This is the type species of the genus and is well known from the original description by Leidy, and the osteology by Scott. A summary of its essential differences from *Hoplophoneus* is given in this paper, consequently no further discussion will be given here. The skull figured is a well preserved specimen in the Princeton Museum (number 10972). Dental formulæ $I\frac{3}{3}C\frac{1}{1}$ $Pm\frac{3}{3}M\frac{1}{1}$.

Length of skull, condyles to premaxillary border,		163mm
"	humerus	172
"	femur	190
"	tibia	168

Dinictis squalidens Cope.

This species was first described from a portion of a deciduous superior canine and a fragment of a mandible supporting the deciduous dentition. Later a mandible containing the permanent dentition was referred to it. The skull figured in the series (number 11379 in the Princeton Museum) contains the permanent dentition except the superior canines, which are just on the point of being replaced. Its reference to *D. squalidens* from the character of the mandible is not to be doubted. The specimen although immature is considerably smaller than *D. felina* and differs from it sufficiently to warrant its reference to a distinct species.

Length of skull, condyles to premaxillary border, 140mm

Dinictis fortis Adams.

This species was described principally from a skeleton. *D. bombifrons*, which, was described from a skull, has since been determined to be a synonym of the former (Amer. Nat., January, '96, p. 50, foot-note). Further material has shown *D. fortis* to be quite distinct from *D. felina*, and now that the skull is known the species may be considered as established. The skull here figured is the one originally described as *D. bombifrons*.

Length of skull, condyles to premaxillary border,		185mm
"	humerus	192
"	ulna	191
"	femur	205
"	tibia	186

D. cyclops Cope.

With this species we take up the John Day forms. The outline drawing here given is from the type skull figured by Cope. The striking features of it are its convex profile, the round orbit and the short temporal space. In a general way it is comparable with *Hoplophoneus cerebralis*, also from the John Day.

Length of the skull condyles to premaxillary border, 150mm

Dinictis brachyops (*Pogonodon brachyops* Cope).

As will be further pointed out in this paper, *Pogonodon* must be considered as a synonym of *Dinictis*. The tooth structure is identical and the dentition differs only in the absence of the second inferior molar, the reduction of which is indicated in other species of *Dinictis*. The figure given in the series is from the fragments of the skull described by Cope. The posterior portion of the skull is reversed and the restoration of the outline is conjectural. The skeleton is in part known and is very Dinictis-like. This species is from the John Day.

Dinictis platycopis (*Pogonodon platycopis* Cope).

This is the largest of the series and with it is probably reached the culmination of the *Dinictis* type as regards size. The profile of the skull was probably more convex than is indicated in the figure, which is taken from Cope's Tertiary Vertebrates, since the specimen is slightly crushed. It is comparable with *H. occidentalis* although exceeding it in size. The skeleton is not known. The type specimen is from the John Day.

Length of skull, condyles to premaxillary border, 235^{mm}

The foregoing series of *Dinictis* species, of which the skulls are figured in Plate XII, although less perfectly known than the *Hoplophoneus* series, is comparable with it. The genus *Dinictis* stands ancestral to the genus *Hoplophoneus* and, from what we know, seems to have been more conservative. In both there is a striking gradation in size. *Hoplophoneus* is greatly diversified in the White River. *Dinictis* remains are not so abundant and three of the six species are known only from the John Day, while only one species of *Hoplophoneus* is known from that formation. The range of the species in so far as I can report them is expressed in the following table.

	White River.			John Day.
	Titanotherium Beds.	Oreodon Beds.	Protoceras Beds.	
Dinictis fortis	×	×		
" felina		×	×	
" squalidens		×		
" brachyops				×
" platycopis				×
" cyclops				×
Hoplophoneus primævus		×		
" oreodontis		×		
" robustus		×		
" insolens		×	×	
" occidentalis		×		
" cerebralis				×

Nomenclature and Synonyms.

The following short account of the history of the genus *Machærodus* may not be out of place here, since this genus gives its name to a subfamily and its priority seems to be somewhat questioned.

Isolated teeth were first noticed by Cuvier in 1824, to whom specimens discovered in the Vald' Arno were exhibited by Nesti. From evidence relative to their association with remains of *Ursus*, Cuvier was induced to refer them to that genus under the name *Ursus cultridens* (Supplement to Ossamens Fossiles, vol. v, Pt. ii, p. 517). The first description is due to Nesti, according to M. de Blainville, who cites his "Lettera terza dei alcune ossa fossile non peranco descritte al Sogn. Prof. Pali Savi, Pisa, 1826," in which the name *Ursus trepanodon* is used, whence later the genus *Drepanodon*, from the species name *trepanodon*, was evidently made. Later M. Bravard described *Felis meganteron* (now known as *Machærodus meganteron*) and conjecturally restored a portion of a skull by adding to it a canine of the character previously described as *Ursus cultridens*, referring it to the genus *Felis* under the specific name *cultridens* proposed by Cuvier (Monograph de deux Felis, p. 143, 1828). Kaup in Description d'Ossemens fossiles der Muséum de Darmstadt, 1833, laid stress on the differences which the falciform canines present as compared with known bears and felines, pointing out their differences from the teeth of other carnivores in the curved form and denticulate margins and proposed a distinct genus, *Machærodus*. An associated incisor he referred to a new genus *Agnotherium*, not recognizing that it probably belonged to the same individual. The real affinities had been recognized by Bravard, but Kaup was the first to propose a generic name for this type of dentition.

In De Blainville's Osteographie, under a description of *Felis meganteron* (*Machærodus meganteron*), a very full discussion is given in which he presses Bravard's claims. Pomel has also sought to substitute the species name *meganteron* for Kaup's *Machærodus*. Finally Bronn in *Lethea Geonostica* has attempted to combine *Smilodon* Lund, and *Machærodus* Kaup under the generic name *Drepanodon*, using Nestis' species name.

The first Machærodont fossil found in North America was described by Leidy and Owen as *Machærodus primævus*. Later Leidy used for this species the generic name *Drepanodon*. Likewise Cope first described species under this genus *Machærodus*. Later, however, he removed them all to new genera. In referring to European species he used the genus *Drepanodon*

with *Machærodus* as a synonym, but retained *Smilodon* as a distinct genus (Extinct Cats of North America, Amer. Nat., 1880).

It has not been definitely shown as yet that there are any representatives of the genus *Machærodus* in North America. In the American Naturalist, 1887, Cope proposed *M. catacopis* on the anterior portion of a mandible having a moderate flange and containing the roots of the incisors and a canine with a posterior denticulate border. It is not distinguishable from *Hoplophoneus* however. Cragin in Science, 1892, proposed *M. crassidens* on feline remains from the same beds and Williston has since (Kansas University Quarterly, 1895) referred other bones from the same locality to this species. None of the species can be said to be established as belonging to the genus *Machærodus* since the generic characters of dental formula, structure of the molar series and the basi-cranial foramina are not determinable in the specimens thus far found in the Loup Fork.

Smilodon is distinctively an American genus. It was established by Lund, 1842, on a specimen from Brazil (*S. neogaeus* K. Danske Vid. Selsk. Copenhagen). Leidy described a fragment of a maxilla containing a sectorial under the name *Trucifelis fatalis*. In structure the tooth agrees with *Smilodon* and a second specimen induced Cope to refer it to that genus. *Smilodon floridanus* Leidy is known from a well preserved skull from which the teeth have been lost.

The genus *Eusmilus* was established by Gervais (*E. perarmatus*, Journal de Zoologie, 1875). Previously Filhol had described *M. bidentatus*, which is synonymous, consequently Gervais genus and Filhols species are accepted.

Dinobastis Cope, although founded on very limited material, will probably prove to represent the latest development of the Machærodont type in North America. The genus is based upon the absence of the internal root of the superior sectorial.

The genus *Dinictis* has remained well defined since first proposed by Leidy. To it, however, should be referred the two species of *Pogonodon* described by Cope. The genus *Pogonodon* as proposed by Cope does not differ from *Dinictis* as regards tooth structure, and the absence of the second inferior molar, which in *Dinictis* is much reduced, is not sufficient grounds for retaining it as a distinct genus, since in several specimens of *Dinictis* it is variable in size and in one is absent from one side. The genus *Dinictis* as thus constituted shows the reduction of this tooth, just as *Hoplophoneus* shows the reduction of the superior premolar.

The genus *Hoplophoneus* proposed by Cope embraces, besides new species, others previously described under the generic

names *Machærodus* and *Drepanodon*. *Dinotomius atrox* Williston is a synonym of *H. occidentalis*, as has been shown by the writer (Amer. Nat., January, 1896).

The genera *Archælurus* and *Nimravus* have remained as first defined.

Our knowledge of North American fossil forms of the true Felinæ is very limited. Leidy has described *Pseudælurus intrepidus*, referring it to the European genus established by Gervais. There are several imperfectly known species of *Felis*. Leidy has described *F. atrox* and *F. augustus*. *Felis imperialis* Leidy is not sufficiently characterized to be retained. Scott has described ? *F. maxima* from a humerus found in the Loup Fork of Kansas. It will be remembered that remains from that deposit have been described under the genus *Machærodus*, and it is not probable that this humerus belongs to a different genus although further material must be found before the affinities of these forms can be determined. The genus *Uncia* Gray cannot be distinguished with certainty in fossil forms and is here included in *Felis*.

The Dentition of the Felidæ.

The modifications of the dentition of the Felidæ consist, on the whole, of the reduction of the number of teeth until almost the entire function of the molar series is performed by a single large sectorial in each jaw and, accompanying the reduction in number, an increase in size and complexity of structure whereby the individual teeth become more perfect cutting instruments.*

The specialization of one tooth as a sectorial to the exclusion of the others appears to be due to the following causes. It is to be observed that when a cat devours a carcass it cuts off masses by a shearing action of the jaws. In so doing the part to be divided is brought to the canthus or angle of the soft wall of the mouth, which is just at the front of the masseter muscle, at which point the greatest amount of force is gained, since the weight is brought immediately to the power. The first inferior molar situated at this point can be most effectively used and has developed into a sectorial. Inasmuch as the inferior and superior teeth do not directly oppose each other but form an alternate series, the first inferior molar more nearly opposes the last upper premolar and this tooth has become the superior sectorial. The shortening of the jaw which accompanied the reduction of the molar series has brought the canines nearer to the powerful muscles of mastication and they are as a result more effective weapons in the Felidæ than in other carnivores.

* Origin of Specialized Teeth of the Carnivora, Cope, Amer. Nat., p. 171, 1879; Mechanical Genesis of Tooth-forms, Ryder, Proc. Acad. Nat. Sci., 1878.

The cause of the reduction of the molar series seems to lie in the following facts. If the jaws of one of the primitive Felidæ are examined it will be found that when they are closed the teeth which first come in contact are the sectorials, because of their elevated crowns. The premolars being further from the condyles are the last to come in contact. The function of seizing and holding is performed by the greatly developed canines and the function of cutting by the sectorials, hence no important function devolves upon the anterior pre-molars and posterior molars. Inasmuch as the lower series bite in front of the upper, it will be seen that the last inferior molar and the first superior premolar are only partially opposed by the teeth of the opposite series, consequently they are less functional and are the first to disappear.

The most primitive form of superior sectorial among the Felidæ consists of a principal, posterior, and antero-internal cusps, as is seen in *Dinictis*. To this form there is added in *Hoplophoneus* an incipient anterior basal cusp which in *Machærodus* is well developed. In *Smilodon* there is a second anterior basal cusp. The internal cusp present in *Dinictis* disappears in later genera, where it is represented only by a convex buttress, which descends from the principal cusp, and, as a more perfect shearing action is developed, this becomes less prominent until in *Dinobastis* it is absent and the internal root which supported it is lost.

The inferior sectorial in the most primitive genera consists of a principal, anterior, posterior and postero-internal cusps. The fate of the internal cusp is similar to that of the internal of the superior sectorial. Since it meets with no opposing cusp it is soon lost. The posterior cusp or heel is reduced in genera in which the superior molar is rudimental and does not oppose it. In *Eusmilus dakotensis*, it becomes a mere sharp line on the posterior border of the principal cusp. The function of the inferior sectorial devolves chiefly upon the principal and anterior cusps, which are well developed.

As the number of teeth was reduced the individual teeth become larger and the premolars developed posterior basal cusps by the elevation of the cingulum, as is seen in *Felis*. The incisors also became more robust in the Machærodont genera. In *Dinictis* they are small and form an even series. In *Hoplophoneus* they are more robust, and in *Dinobastis* we see their most specialized form. In this genus they have minute basal cusps and their margins are crenulated.

The development of saber-like canines characteristic of the Machærodont type is easily traced in *Archælurus*, in which the inferior and superior canines are sub-equal; in *Æluroqale*, where the posterior border is denticulate, and then in *Dinictis*, where both the anterior and posterior borders are denticulate.

With the higher genera they attained an enormous development, such as would seem to have been a positive hindrance in biting and seizing. In the true cats the canines remained sub-equal although developing to a great size.

The development of a flange on the anterior inferior portion of the mandible is to be correlated with the lengthening of the superior canines. Its function seems to have been to protect these teeth, but in the latter genera the length of the flange evidently was not as great and the canines extending below the mandible were effective weapons when the mouth was closed. The most primitive forms probably possessed no flange since the canines were short and sub-equal. In *Archælurus* we see the first indication of a developing flange in the obtuse angle of the mandible and the shallow fossa in which the superior canine rests.

The evolution of the Felidæ is best indicated in the characters of the dentition. It is upon the dental formulæ and dental structure that generic distinctions rest, and a careful study of these points will reveal the genetic and phylogenetic relationships of the family.

The Succession of Genera.

There are two distinct types of development among the Felidæ. Of these the Machærodont type seems to have had its origin in America, since with the exception of *Ælurogale* and possibly *Machærodus* all the genera have been found here. The Old World was probably the home of the true cats, as it seems to be to-day. The only representative of them in America previous to Pliocene times was *Pseudælurus*, of which genus only one specimen has thus far been found. This genus may have been acquired through Oligocene intermigration, and the genera *Ælurogale* and *Machairodus* are probably European descendants of American forms.

Any attempt at a phylogenetic arrangement of the Felidæ must coincide with the occurrence in time, the order of reduction of the dental series, and the development of the individual teeth, particularly the sectorials. It is proposed herein to show that there is a succession of genera of the two types above mentioned which meets these requirements.

Of the Machærodont type the somewhat problematical form from the Bridger described by Wortman as ? *Patriofelis leidyanus* is the most primitive. From it *Dinictis** is derivable, through the reduction of the size of the postero-internal

* *D. fortis* has been described as having the second lower molar very rudimental. In a specimen in the American Museum this tooth is absent from one side. In *D. paucidens* described by Mr. Riggs in the Kansas University Quarterly, April, 1896, it is absent from both sides. The dental formula of *D. fortis* is thus M $\frac{1}{2-1}$, *D. paucidens* probably being a synonym.

cusp of the inferior sectorial and a modification of the heel. Thus is reached the most primitive species of the genus. Within the limits we can trace the reduction of the second inferior molar from a small two-rooted tooth to a mere tubercle and finally find it entirely absent in *D. platycopis*. The genus *Hoplophoneus* is well separated from *Dinictis* through the development of an anterior basal cusp on the superior sectorial and the loss of the internal cusp. The internal cusp had already shown some signs of reduction in certain specimens of *Dinictis* in that it had become lower and less distinct. Moreover, *Hoplophoneus* has lost the second inferior premolar and within the genus we can trace the reduction and final disappearance of the second superior premolar. The postero-internal cusp of the inferior sectorial, which had shown signs of variation in *Dinictis*, is absent in the higher species of *Hoplophoneus*. The rapidly diminishing dental series reaches its maximum reduction in *Eusmilus*. Of this only the inferior dentition is known. It differs from *Hoplophoneus occidentalis* in the loss of an incisor, the reduction of the heel of the sectorial in *E. bidentatus* and its absence in *E. dakotensis*. This is the only genus in which the incisors have suffered a reduction in number, although in some specimens of *Hoplophoneus* the internal ones are much reduced.

With the formula $I\frac{3}{3}C\frac{1}{1}Pm\frac{2}{2}M\frac{1}{1}$ the most stable form of Machærodont dentition seems to have been reached, since it has given rise through the addition of basal cutting lobes to genera which persisted until Pleistocene times. The genus *Machærodus* differs from the genus *Smilodon* in having a second basal lobe developed on the molar series. They are further distinguished by the fact that in *Smilodon* the post-glenoid and post-tympanic are coössified. The absence of the entepicondylar foramen in the specimen of *S. necator* figured by Cope* cannot be considered of generic importance since Burmeister has shown that it is present in three specimens which he has described.† Its absence in the case above mentioned is probably due to individual variation. The most specialized genus as regards the structure of the teeth is *Dinobastis*. In *Hoplophoneus* the internal cusp of the superior sectorial has disappeared and the root supports a convex buttress. This is also the case in *Machærodus* and *Smilodon*, but in *Dinobastis* even the internal root has disappeared. The incisors also present a peculiarity, which is seen in some specimens of *Machærodus* and *Smilodon*, in the possession of minute basal cusps and crenulate margins. With this genus the Machærodonts culminated in specialization of tooth structure as they did in

* Amer. Nat., 1880, p. 857.

† Description physique de la Republique Argentine, Text in Atlas, p. 106.

Eusmilus in the reduction of the dental series, and with this form they become extinct although it is probable, judging from fossil remains, that the dominant genus in Pleistocene times was *Smilodon*.

The genera *Archælurus*, *Ælurogale* and *Nimravus* seem to represent specialized forms of more primitive genera, forming a side line of development. Of these *Archælurus* is most primitive. It is not directly derivable from any known form nor does it stand ancestral to the genera of Machærodonts previously discussed. The superior sectorial consists of a principal and a posterior cusp. There is a slight convexity in the position occupied by the anterior basal cusp in *Hoplophoneus*. The same thing is seen in *Nimravus*, but it does not develop into a true cusp. The principal cusp has a convex internal buttress as in *Hoplophoneus*. The inferior sectorial consists of an anterior, principal and posterior cusp or heel. From this genus *Ælurogale* could be derived by the loss of the first superior premolar. There is also a different development of the canine, the tooth becoming longer, recurved and acquiring a posterior denticulate margin. *Nimravus* differs in dental formula from *Ælurogale* in the loss of the second inferior premolar. The canine, however, is the most striking feature of this genus: it is nearly straight and spike-shaped, a form which is seemingly not derivable from *Ælurogale* but rather from *Archælurus*. *Ælurogale* is a European genus and although indicative of the order of reduction of the teeth in this small and seemingly aberrant group, it cannot be said to occupy an intermediate position between the other two genera. These three genera differ from other Machærodonts in the order of reduction of the teeth, all having retained the second inferior molar. This tooth is, however, on the point of disappearing in *Nimravus*, as is indicated by its absence on one side in a second specimen of *N. gomphodus*. *Archælurus* exhibits a peculiarity which should not be overlooked, in the strange deflection or exostosis of the border of the mandible posterior to the molar series. Of this a trace is seen in *Nimravus*.

Of the true cats there is but one genus which is known only as an extinct form, namely *Pseudælurus*. *Felis*, *Lynx* and *Cynælurus*, however, are known as fossils. *Pseudælurus* presents the most primitive dental formula and one which can be compared with *Dinictis* as regards tooth structure, but it differs in the absence of the second inferior molar. *Pseudælurus* probably gave origin to *Felis* through the loss of the second inferior premolar. *Cynælurus* differs from *Felis* in the absence of the internal cusp of the superior sectorial and the somewhat imperfect retractility of the claws. It forms a side development from the main line of descent. In

the genus *Felis* there is a tendency to the loss of the second superior premolar, it frequently being absent in old individuals. and thus is indicated the probable derivation of the genus *Lynx*. This genus occasionally loses the superior molar and so in exceptional cases we arrive at a dentition comparable with that of *Eusmilus*, the extreme reduction, however, taking place in the other jaw. In several species of *Felis* posterior cutting lobes are added to the premolars and an anterior basal cusp is indicated on the superior sectorial. Comparing the dentition with that of *Machærodus* or *Smilodon*, it differs in the retention of the internal cusp of the superior sectorial and the presence of an additional superior premolar.

Phylogeny of the Felidæ.

Present systems of classification.

Cope, in his publication on the "Extinct Cats of North America,"* has based his classification upon the basi-cranial foramina, making two families, the Felidæ and Nimravidæ, according to the following definitions.

Felidæ.—No distinct carotid foramen nor alisphenoid canal, condylar foramen entering the foramen lacerum posterius. No post-parietal and generally no post-glenoid foramina.

Nimravidæ.—Carotid and condylar foramina entirely distinct from the foramen lacerum posterius; an ali-sphenoid canal and post-glenoid and post-parietal foramina.

This classification includes Machærodont members in each family. *Proælurus* is considered as the genus from which the true Felidæ may have been derived through *Pseudælurus*, if indeed these two genera are not the primitive members of that family. The Machærodont members of the Nimravidæ are suggested as the ancestors of the Felidæ. It should be remarked here that Cope's classification, based upon structural characters, does not permit of a phyletic interpretation, since the families as constituted by him are of polyphyletic origin as I interpret his meaning.

Zittel† establishes three subfamilies, the Proælurinæ, Machærodinæ, and Felinæ, defining them as follows:

Proælurinæ.—Dental formula $\frac{3}{3}$, $\frac{1}{1}$, $\frac{4}{4}$, $\frac{1}{2}$, lower carnassial with strong cutting talon skull elongated. Lower jaw slender, small in front with curved lower border; long-legged, fore and hind feet semi-digitigrade and pentadactyl.

Machærodinæ.—Dental formula $\frac{3}{3-2}\ \frac{1}{1}\ \frac{4-2}{3-1}\ \frac{1}{1}$. Upper canine large and powerful, saber-shaped, compressed with anterior and posterior cutting edges. Front pms more or less reduced.

* Cope, Amer. Nat, 1880, p. 834.
† Handbuch der Paleontologie, 1893.

Upper carnassial with or without anterior basal cusp. Lower carnassial with talon. Lower jaw flattened at symphysis and separated from the lateral face by an angle. Lower border straight, more or less flared down in front. Femur frequently with third trochanter.

Felinæ.—Dental formula $\frac{3}{3}\ \frac{1}{1}\ \frac{2-3}{2-3}\ \frac{1}{1}$. Canine conical, upper and lower of about the same size; the two anterior pms lost. Upper carnassial with strong anterior basal cusp. Lower carnassial without talon. Upper molar reduced, lower one lost. Lateral surface of mandible not separated from the symphysis by an angle.

The Proælurinæ include *Proælurus* Fil. and *Pseudælurus* Gerv., but some doubt is expressed concerning the relations of *Proælurus*. From the creodont *Palæonictis* he derives the Machærodinæ, using Wortman's* suggestion in this respect, while from an independent source in the Creodontia he derives the Cryptoprocta and Felinæ through *Proælurus*.

Schlosser† in Affen Lemuren, u. s., in criticising Filhol, expresses the opinion that *Pseudælurus edwardsi* is a true cat, while *Proælurus*, *Pseudælurus intermedius* and the problematical Cryptoprocta belong to another line. He points out clearly the Viverine relationships of *Proælurus* and rejects it as a probable cat ancestor; otherwise he accepts Cope's classification of the Felidæ.

Proposed phylogeny.

As will be seen, these authors mutually criticise each other. The determination of the relationships of Proælurus removes the possibility of its being the ancestor of Pseudælurus and the true cats, as has been suggested by Cope, and also destroys the subfamily Proailurinæ as established by Zittel. The unusual method of classification employed by Cope and accepted by Schlosser in this family, whereby Machærodont genera are grouped with the true cats, is avoided by Zittel's subfamilies Machærodinæ and Felinæ. These two subfamilies are the equivalents of the Machærodontinæ and Felinæ proposed by Gill‡ and his classification is here accepted, since it has the priority, however referring *Cynælurus* to the Felinæ, inasmuch as the separation into a distinct subfamily Guepardinæ cannot be maintained. The points upon which the Guepardinæ was established are the non-retractility of the claws and the absence of the inner cusp of the superior sectorial. The claws are retractile although less perfectly so than in other

* Wortman, Ancestry of the Felidæ, Bull. Ann. Mus., vol. iv, p. 94.

† Schlosser, Affen Lemuren, u. s., 1887, p. 420.

‡ Theodore Gill, Smithsonian Miscellaneous Collection, 230, Arrangement of the Families of Mammals, 1872.

Felidæ, and the absence of the cusp is not of sufficient importance, as would be judged by the absence of the same character in certain of the Machærodontinæ.

The subfamilies may be defined as follows, slightly modifying Gill's definitions:

Machærodontinæ; superior canines large and powerful, usually saber-shaped with posterior and anterior denticulate borders, the inferior canine not greatly exceeding the outer incisor. Symphysial portion of the mandible separated from the lateral surface by an angle, the anterior inferior border of the ramus produced into a flange or making an obtuse angle with the symphysial portion.

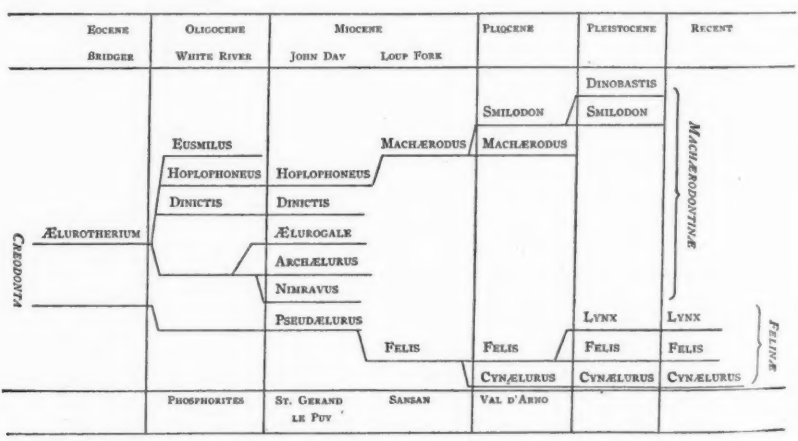
Felinæ.— Canines sub-conical and sub-equal, inferior and lateral faces of ramus continuous with the symphysial.

The Machærodontinæ as thus constituted include a group which is in some respects intermediate between the two subfamilies but which do not stand ancestral to any genera of either of them and are not derivable from them. They are *Archælurus*, the European genus *Ælurogale* and the peculiar *Nimravus*. *Archælurus* and *Nimravus* have been called by Cope the "false-sabre-tooths." *Archælurus* in general appearance is very suggestive as to what was the probable ancestor of the Machærodontinæ, but its late appearance and specialized tooth structure show that it could not have given rise to any known form outside of the genera above mentioned. On the removal of the matrix from one of the specimens I found that the internal cusp of the superior sectorial is wanting in *Archælurus*. The same also proved to be true in *Nimravus*, although reported as present in each by Cope. Moreover the posterointernal cusp of the inferior sectorial is wanting in *Nimravus* and probably in *Archælurus*. Thus there is found to be the same tooth-structure in these two genera that is seen in *Ælurogale*. It is therefore demonstrated that although the dentitions of these genera are more primitive as regards numbers, they could not have given rise to other Machærodonts or to the Felinæ. These three genera are related in the order of the reduction of the dental series, the character of the mandible and the structure of the canines. The canines of *Archælurus* have a convex anterior border and a posterior cutting edge, but in its present state of preservation shows no signs of denticulations. The canine of *Ælurogale* has the posterior border denticulate. The peculiar spike-shaped canine of *Nimravus* is very suggestive that this genus marks the end of an aberrant phylum.

The subfamilies stand entirely distinct from each other and well separated from the Creodonts. In the subfamily Machærodontinæ there is, as has just been shown, a small group which stands in a peculiarly isolated position. There is, how-

ever, a specimen which may be considered as a probable ancestral form of all the Machærodontinæ and brings them a step nearer the Creodonts. It is the jaw fragment from the Bridger Eocene (number 11375 in the Princeton Collections) which Wortman has described as ? *Patriofelis leidyanus* (Am. Mus. Nat. Hist. Bull., 1892) as a probable connecting link between the Creodont *Paleonictis* and the Felidæ. A further knowledge of *Patriofelis* induced him to remove it from that genus (ibid., 1894). For the sake of reference I propose the generic name *Ælurotherium*. *Ælurotherium leidyanum*, following the description given by Wortman, consists of a jaw fragment containing the third and fourth premolars and the first molar or sectorial. It also bears a distinct trace of the alveolus for the canine, the position of which is such as to preclude the possibility of there being more than three premolars. The sectorial, as will be seen from a comparison with *Dinictis*, presents the same elements as that genus but has a much better developed postero-internal cusp and heel, thus fulfilling the requirement of an ancestral form. From what can be judged from the wear of the cusps and the relation of the teeth in the Felidæ it seems probable that it possessed the dental formula $P\frac{4}{3}M\frac{1}{2}$ as was inferred by Wortman, thus exceeding the dental formula of *Dinictis* by a premolar. It will be noted that the dental formula of *Ælurotherium* was probably more primitive than that of Archælurus, thus not precluding the possibility of its being ancestral to that genus also, although probably quite removed from it.

The following arrangement according to subfamilies expresses the probable line of descent of each as well as the occurrence in time of the various genera.



There is a point of difference among the two sub-families which should be discussed here. It is the character of the basi-cranial foramina which was made by Cope a basis of classification. The arrangement of the foramina and the presence of the alisphenoid canal as found in those genera which he made to constitute the Nimravidæ is such as is found in primitive forms. It is not unnatural that the higher forms should have paralleled each other in the loss of the alisphenoid canal and the disposition of the foramina, so that in *Smilodon* and *Felis* we find the same conditions although the two genera represent the most specialized forms of the phyla in which the basi-cranial characters are known. The two subfamilies exhibit a most remarkable parallelism in development. The point of divergence from a common ancestor is quite removed from the position by the most primitive of the well known genera. Indeed it is not impossible that the Felidæ may have had a separate origin from the Creodonts, but our knowledge of their early relationships is too meagre to justify any definite conclusions on this point. As we know them the phyla are distinct.

The following key for determining the genera of the Felidæ is submitted. *Ælurotherium* not being well known is contrasted with *Dinictis*, which it most resembles in the characters known. *Eusmilus*, being known only from the lower dentition, is contrasted with *Hoplophoneus*.

I. Superior canines large and powerful, usually saber-shaped with posterior and anterior denticulate borders. Inferior canine not greatly exceeding the outer incisor. Mandible with the symphysial portion separated from the lateral by an angle, the anterior inferior border of the ramus with a flange or making an obtuse angle with the symphysial portion.

MACHÆRODONTINÆ.

A. Anterior inferior border of mandible with an obtuse angle.
  a. Superior sectorial without internal cusp.
    a.a. Superior canine recurved posterior border, not denticulate.
      1. Dentition $I\frac{3}{3}C\frac{1}{1}Pm\frac{4}{3}M\frac{1}{2}$ *Archælurus.*
    b.b. Superior canine recurved posterior border, denticulate.
      2. Dentition $I\frac{3}{3}C\frac{1}{1}Pm\frac{3}{3}M\frac{1}{2}$ *Ælurogale.*
    c.c. Superior canine spike shaped.
      3. Dentition $I\frac{3}{3}C\frac{1}{1}Pm\frac{3}{2}M\frac{1}{2}$ *Nimravus.*
B. Anterior inferior border of mandible with a flange.
  b. Superior sectorial with internal cusp.
    d.d. Inferior sectorial with strong postero-internal cusp and talon.
      4. Dentition ? $I\frac{3}{3}C\frac{1}{1}Pm\frac{4}{3}M\frac{1}{2}$ *Ælurotherium.*
    e.e. Inferior sectorial with small postero-internal cusp, talon reduced.

5. Dentition $I\frac{3}{3}C\frac{1}{1}Pm\frac{3}{3}M\frac{1}{2-1}$ *Dinictis.*

c. Superior sectorial without internal cusp.

ff. Anterior basal cusp of superior sectorial, incipient premolars without basal cusps.

6. Dentition $I\frac{3}{3}C\frac{1}{1}Pm\frac{3-2}{3}M\frac{1}{1}$ *Hoplophoneus.*

7. Dentition I/2C/1Pm/1M/1 *Eusmilus.*

d. Anterior basal cusp of superior sectorial well-developed, no internal cusp, premolars with basal lobes.

gg. Superior sectorial with single anterior basal cusp, post-glenoid and post-tympanic processes distinct.

8. Dentition $I\frac{3}{3}C\frac{1}{1}\frac{2}{2}M\frac{1}{1}$ *Machærodus.*

hh. Superior sectorial with a second anterior basal cusp, post-glenoid and post-tympanis processes coössified.

9. Dentition $I\frac{3}{3}C\frac{1}{1}Pm\frac{2}{2-1}M\frac{1}{1}$ *Smilodon.*

ii. Superior sectorial without internal root.

10. Dentition probably like *Smilodon*, *Dinobastis.*

II. Canines sub-conical and sub-equal, inferior and lateral faces of ramus continuous with symphysial.

FELINÆ.

B. Anterior and inferior borders of mandible continuous.

e. Superior sectorial with internal cusp.

11. Dentition $I\frac{3}{3}C\frac{1}{1}Pm\frac{3}{3}M\frac{1}{1}$ *Pseudælurus.*

12. Dentition $I\frac{3}{3}C\frac{1}{1}Pm\frac{3-2}{3}M\frac{1}{1}$ *Felis.*

13. Dentition $I\frac{3}{3}C\frac{1}{1}Pm\frac{2}{2}M\frac{1-0}{1}$ *Lynæ.*

f. Superior sectorial without internal cusp.

14. Dentition $I\frac{3}{3}C\frac{1}{1}Pm\frac{3}{2}M\frac{1}{1}$ *Cynælurus.*

EXPLANATION OF PLATES.

PLATE X.

Hoplophoneus primævus, all × $\frac{1}{2}$.

FIGURE 1.—Skull (number 11013 Princeton Museum restored from number 10540.)
FIGURE 2.—Manus (number 10741 Princeton Museum.)
FIGURE 3.—Pes "
FIGURE 4.—Femur "
FIGURE 5.—Ulna and radius "
FIGURE 6.—Tibia and fibula "
FIGURE 7.—Humerus "

PLATE XI.

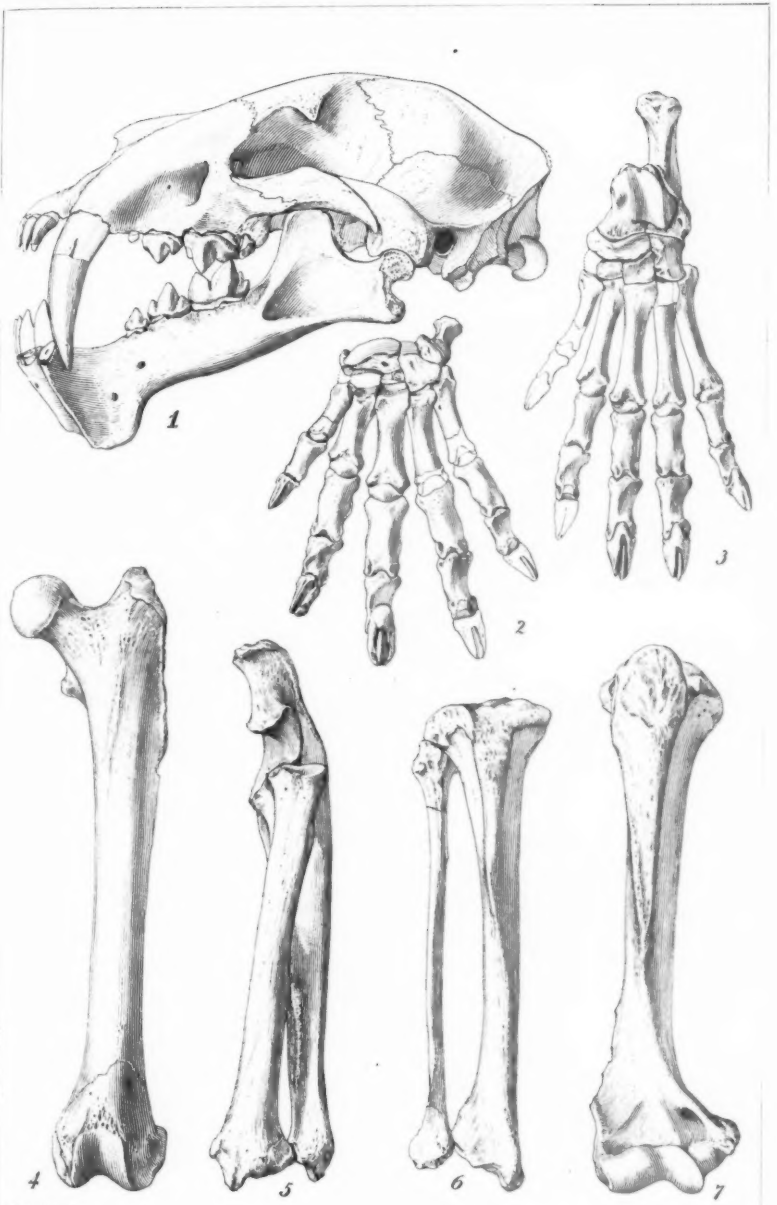
Hoplophoneus series, all × $\frac{1}{2}$.

FIGURE 1.—Hoplophoneus cerebralis (after Cope.)
FIGURE 2.— " oreodontis (10515 Princeton Museum.)
FIGURE 3.— " primævus (11013 Princeton Museum.)
FIGURE 4.— " robustus (650 American Museum.)
FIGURE 5.— " insolens (11022 Princeton Museum.)
FIGURE 6.— " occidentalis (after Williston.)

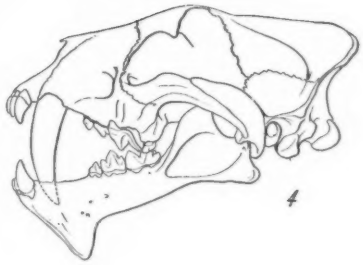
PLATE XII.

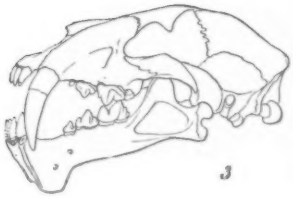
Dinictis series, all × $\frac{1}{4}$.

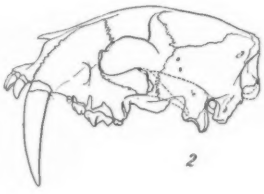
FIGURE 1.—Dinictis squalidens (11379 Princeton Museum.)
FIGURE 2.— " cyclops (after Cope.)
FIGURE 3.— " felina (10972) Princeton Museum.)
FIGURE 4.— " fortis (10502 Princeton Museum.) [reversed.]
FIGURE 5.— " brachyops (Cope's type, Amer. Mus., posterior portion
FIGURE 6.— " platycopis (after Cope.)

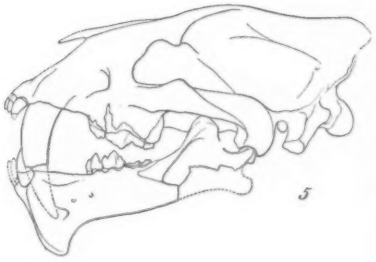


HOPLOPHONEUS PRIMÆVUS, × $\frac{1}{4}$.

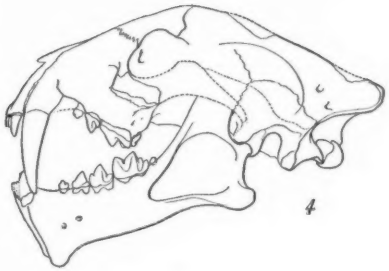








HOPLOPHONEUS SERIES, × ¼.



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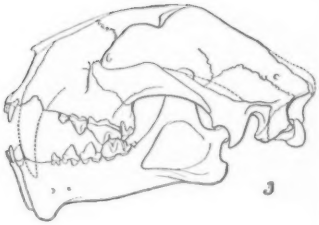

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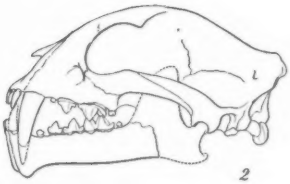

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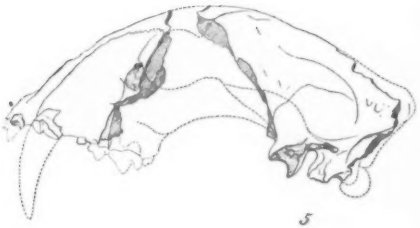

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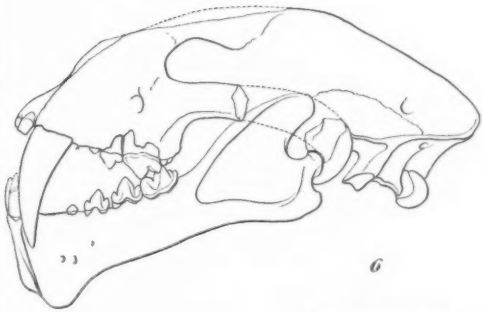

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1

DINICTIS SERIES. $\times \frac{1}{4}$.

ART. L.—*The Age of the Igneous Rocks of the Yellowstone National Park;* by ARNOLD HAGUE, of the U. S. Geological Survey.

THE region embraced by the Yellowstone National Park and the adjoining country to the north and east, has been a center of great volcanic activity. By far the greater part of the surrounding mountains, and the entire park plateau, have been built up by the pouring out of vast accumulations of volcanic material. The region, throughout Tertiary time, was undoubtedly the most active center of eruptive energy to be found in the northern Rocky Mountains.

Under the authorization of the U. S. Geological Survey, aided by an able corps of assistants, I have carefully studied the geological history of volcanic eruptions in the Park country, and the order of succession of the different masses of lavas which make up this enormous body of igneous rocks. To a proper understanding of the geological relations of these volcanic lavas to the earlier crystalline and sedimentary rocks, as well as their relations to the pre-existing mountain ranges, a brief sketch of the geology of the country seems necessary.

In all the mountain ranges which surround and shut in the park, at least a nucleus of highly crystalline rocks of Archean age is exposed. The Tetons, to the south, consist mainly of an Archean mass, which towers high above all later rock formations. In the Absaroka range, stretching along the entire east side of the park and formed mainly of igneous rocks, granites and schists are exposed at the northern end, which soon pass between the later lavas. The Snowy range, which shuts in the park on the north, is largely made up of Archean schists, gneisses and granites, associated with the more recent outbursts of lava. In the Gallatin range, on the west, a body of crumpled gneisses and schists form the nucleus around which have been built up a complex mountain structure, in which the volcanic rocks play an important part in the structural features of the mountains. Resting unconformably upon these Archean bodies, which formed either a broad continental mass, or a group of closely related islands, occurs a great thickness of sedimentary beds, made up in greater part of material derived by the slow processes of denudation of the earlier continental land surfaces. These sediments, thus slowly deposited, built up during Paleozoic and Mesozoic times a series of sandstones, limestones, and shales conformable from base to summit. The basal beds, resting directly upon the Archean rocks, consist largely of siliceous material, passing gradually over into a

shaly limestone, carrying a fauna characteristic of the Middle Cambrian period. These beds have been designated the Flathead formation. Above these beds, in their regular order of succession, come the Upper Cambrian, Silurian, Devonian, Carboniferous, Trias, Jura, and every grand division of the Cretaceous recognized in central Montana and northern Wyoming, including the Dakota, Colorado, Montana, and the Laramie sandstone at the top.

The Montana formation exhibits throughout its entire development a singularly uniform sandstone epoch, the argillaceous beds of the Pierre shales being poorly represented other than by a great thickness of arenaceous deposits. The overlying Laramie, on the other hand, although essentially a sandstone-making epoch, indicates frequent and abrupt changes in its sedimentation. Constantly changing beds of shales, clays, and impure standstones, afford abundant evidence in their mode of occurrence, that the material forming the beds was deposited in a shallow sea. With the close of the Laramie sandstones, the conformable Paleozoic and Mesozoic strata came to an end. The entire region was again elevated above the sea. The sedimentary beds were everywhere uplifted, and very large areas tilted up at high angles. A profound orographic movement took place and the region became one of mountain building on a grand scale, accompanied by plication, folding, and faulting. It was this movement that blocked out the mountains which surround the Yellowstone Park plateau, and indeed all ranges of the northern Rocky mountains. It has been designated the post-Laramie movement. This orographic disturbance was doubtless coincident with the similar movements described by Mr. S. F. Emmons as clearly defined in Colorado, though in the northern country no unconformities such as have been noted to the southward, have as yet been definitely recognized between the Middle Cambrian and the Laramie, as described by Mr. Emmons.* This limitation of the Laramie formation to the beds at the top of the upturned conformable series of sediments, is the line of demarcation first proposed by Mr. Clarence King.† It is in accord with the great physical break which played so important a part in the building up of the northern Rocky Mountains, and brought to a close a period of a distinctly marine or brackish fauna.

In this region there are no evidences that igneous rocks played any part during Paleozoic and Mesozoic times, prior to the post-Laramie movement. There are no intrusive masses nor interbedded flows contemporaneous with the deposition of

* Orographic Movement in the Rocky Mountains, S. F. Emmons, Bull. Geol. Soc. Amer., vol. i, 1890.

† U. S. Exploration of the 40th Parallel, Systematic Geology, vol. i, p. 357.

sediments, nor are there any beds derived wholly, or in part, from volcanic material of later age other than the eruptive masses of the Archean. On the other hand, as will be shown later, closely following and possibly coincident with the Laramie uplift, came the first outpouring of igneous rocks, which, beginning in late Cretaceous time, continued throughout a long period, lasting till near the close of Tertiary time. With the blocking out of the mountains, which accompanied the post-Laramie movement, a largely increased continental land area was formed. Coincident with this elevation of the land, denudation of the continental mass began, and deposition of fresh sediments uncomformable to the uplifted Laramie took place. Within the park region such sediments, if deposited, were either carried away by erosion or buried beneath outflows of later igneous rocks.

Along the northern slopes of the Snowy range, about 45 miles north of the park, these post-Laramie sediments were deposited several thousand feet in thickness under conditions singularly favorable for their preservation.

The lowest rocks resting directly upon these upturned sedimentary beds, are largely composed of friable sandstones derived from the degradation of the Laramie strata. They are soon followed by sands, conglomerates, clays, and grits, varying greatly in texture in different localities, and consisting mainly of material derived from the disintegration of igneous rocks. In places, they consist almost wholly of coarse, acid, andesitic agglomerates, which attain a development of nearly 2,000 feet in thickness.

The volcanic nature of the great body of this material was recognized by Mr. Walter H. Weed,* who first carefully studied it, and this view has been generally accepted by all geologists who have since visited the region. According to Mr. Weed, the beds reach a maximum development of nearly 7,000 feet. He has proposed to designate them as the Livingston formation, after the town on the Yellowstone river where they are well exposed.

Since their deposition the Livingston beds have been uplifted and now lie inclined, dipping away from the mountains, having taken part in subsequent orographic movements which elevated the Rocky Mountains. The limited invertebrate fauna obtained from these beds is as yet too restricted to be of any special value in determining the geological position of the terrane. As regards the flora, however, the collections which have been made from time to time, are more satisfactory and definite as regards specific characters, and Prof. F. H. Knowl-

*The Laramie and Overlying Livingston Formation in Montana, U. S. Geol. Survey Bull., 105.

ton has been able to determine a distinct Livingston flora higher than the Laramie, but far more closely allied to a Cretaceous than a Tertiary flora. The importance of the Livingston formation in the geological history of the region can hardly be over-estimated, from the fact already pointed out that it is the earliest occurrence of an accumulation, either wholly or in part, of volcanic material following the uplift of the Paleozoic and Mesozoic beds.

To the east and north of the Livingston formation, but farther removed from the mountains, occurs a still later series of beds made up of the disintegrated sediments of the earlier rocks, including those of the Livingston formation. Apparently they are identical in age with similar deposits found near the junction of the Missouri and Yellowstone rivers, where they in all probability lie upon the Laramie sandstones without the intervention of any beds referable to the Livingston formation; at least, the latter have not as yet been recognized in this locality. These beds along the Missouri and Yellowstone rivers have long been designated as the Fort Union formation, and have also been of special interest on account of their varied fossil flora, first carefully described by the late Prof. J. S. Newberry. This Fort Union flora is now generally regarded as of Eocene age.

Returning to the immediate region of the Yellowstone Park, the Laramie sandstones are found at a number of localities, but neither the Livingston nor Fort Union beds are exposed, and if ever deposited, have been removed by erosion or buried beneath later igneous outflows. Subsequent to the post-Laramie movement and after a very considerable erosion of the uplifted sandstones, volcanic action broke out with great energy in the Park country. From numerous centers of eruption lavas were thrown out, submerging broad areas of country. Volcanoes of great size surrounded the Park on the east, north, and northwest. The Absaroka Range was built up by the pouring forth of vast accumulations of volcanic ejectamenta, burying the greater part of the earlier range beneath many thousands of feet of accumulated lavas. These volcanoes followed the lines of orographic movement which took place at the close of the Laramie, along what are now the Absaroka, Snowy, and Gallatin ranges. To-day, this ancient center of eruption lies in the interior of the continent just eastward of the continental watershed which separates the waters of the Atlantic from those of the Pacific, but at the time this vast body of lavas was ejected, they built up a remarkable chain of coast volcanoes along the western shore-line of a gradually retreating ocean.

This volcanic energy continued throughout a long period of time with intervals of comparative rest, as shown by the evidences of erosion of the ejected material, and followed by renewed activity in the outpouring of fresh lavas. In many localities in the world the age of volcanic flows has been more or less definitely determined by the fortunate preservation of a fauna or flora in some lake beds formed in a depression or basin in the volcanic rocks, and these again preserved by beds of later compact lava or mud flows. These in a number of instances determine the age of the underlying and overlying flows, but are of slight value in determining the relative age of other eruptions in the adjoining regions. It is doubtful if any region in the world furnishes a more complete geological record of volcanic eruption from beginning to end throughout so long a period of time as the Yellowstone Park and the adjoining mountains.

As regards the problem connected with the relative age of the different masses of igneous rocks, the prosecution of the work has been greatly advanced by the field study of the so-called fossil forests and the many localities where a varied flora has been well preserved in the tuffs and waterlain deposits. The mode of occurrence of the beds carrying a fossil flora has been carefully examined and large collections made from time to time. Prof. Lester F. Ward and Prof. F. H. Knowlton passed the season of 1887 in the Park. In the following year, Professor Knowlton accompanied me to the field for the purpose of collecting from all the known localities, adding largely to the store of material previously obtained. All these collections were submitted to him for study, and his results when published will form an important chapter in the monograph upon the Yellowstone Park, soon to be published by the U. S. Geological Survey.

All references in this paper to the genera and species found here are based upon the identifications of Professor Knowlton.

The oldest extrusive flows recognized in the Park are a series of light-colored coarse breccias and fine tuffs composed of hornblende-andesite, and hornblende-mica-andesite, varying greatly in texture and physical habit, but grouped together under the general description of early acid breccias and flows. It is evident that they were thrown out from different centers of eruption, and in every instance, so far as can be told, they were the earliest eruptions from those recognized centers. In general, these early acid breccias occur as relatively small isolated bodies exposed by erosion of the later rocks. In this way they occupy the bottom of the deep valley of Cache Creek in the Absaroka Range, they are found in the deeper gorges of Tower Creek basin, and are found as far westward

as Sepulchre Mountain. They are, however, best exposed in the northwest corner of the Park on both sides of the Yellowstone River, where the overlying lavas have undergone the greatest amount of denudation. Here they rest directly upon the Archean rocks of the Snowy Range, and in sharp contrast to the later lavas carry a large amount of crystalline gneisses and schists imbedded in the breccias. On Crescent Hill, just south of the Yellowstone River, these early acid breccias are well shown over 1,000 feet in height, in a steep slope facing northward. The finer tuffs, ashes, and mud flows have afforded exceptionally favorable conditions for the growth and preservation of a rich and varied flora. At Crescent Hill, Elk Creek, and on both banks of the Yellowstone River, below the mouth of Elk Creek, large collections of plant remains were obtained, which have since been studied by Professor Knowlton. From this abundant flora he has identified 79 species, of which 42 species are either new to science or now specifically determined. Of the remaining 37 species that have been found elsewhere, 17, or nearly one-half of them, are already known in beds belonging to the Fort Union formation. Of the remaining species, 5 come up from the Laramie, 5 are found in the Livingston and Denver beds, and 11 species are also common to the Auriferous Gravels of California. This flora from the acid breccias is otherwise so closely allied to early Tertiary forms that Professor Knowlton has no hesitation in referring the entire group to the Eocene period, and correlating it with the Fort Union horizon.

The following characteristic species have been determined from the acid breccias: *Sapindus affinis*, *Cornus acuminata*, *Populus speciosa*, *Sequoia couttsiæ*, *Asplenium magnum*, *Taxites ulriki*, *Populus daphnogenoides*, *Populus xantholitheusis*, *Betula iddingsii*, *Fagus undulata*, *Aralia notata*. This reference to the Eocene is in accord with the geological evidence which makes these andesitic lavas carrying the flora younger than the Livingston formation, and among the earliest of the extrusive rocks of the Park.

Overlying this group of early acid breccias comes a great accumulation, in places several thousand feet in thickness, of volcanic ejectamenta, and also like the earlier rocks, made up of coarse and fine material presenting great differences in texture and physical habit, whose character is determined in great part by their mode of occurrence and the distance from their sources of eruption. Like the early acid breccias, they have been grouped together into one series representing a distinct phase of the volcanic phenomena of the region. Unlike the earlier breccias, however, they are distinctly basic in com-

position and consist mainly of hornblende-pyroxene-andesites, pyroxene-andesites, and basalts.

By far the greater part of this erupted material is formed of coarse agglomerates, somber in color, with interbedded sheets of compact basalt varying in extent, and of greater or less thickness. These basic breccias cover large areas of country, extending from the Gallatin Range westward across the Snowy Range, along the nothern border of the Park. They constitute nearly all the northern portion of the Absaroka Range. Indeed, they may be said to cover the greater part of the northwest corner of the Park. Over this extensive area the basic breccias are only seen in a few localities resting directly upon the earlier acid rocks, but where exposed, they are for the most part easily recognized by their sharp contrast in color, texture, and mineral composition. In places along their contact the acid breccias show evidence of considerable erosion before the pouring out of basic flows, but in other localities they exhibit a transition from one series of rocks to the other and occasionally a mingling of both groups.

On the ridge about one mile south of Yanceys Station and within a short distance of Elk Creek, and again near Lost Creek, these basic rocks lie directly upon the acid rocks in a series of fine agglomerates and mud flows. The acid rocks present a very hilly and uneven surface, with the basic rocks frequently lying at a lower level and occupying depressions in the older lava.

Possibly in some instances erosion washed down the softer material from both series of rocks, causing a mingling of both acid and basic lavas, and rendering it impossible to discriminate between beds. Apparently similar conditions prevailed on the opposite side of the Yellowstone River along the northern escarpment of Specimen Ridge, extending eastward as far as Crystal Creek, where both series of rocks are again seen together. It is evident that the belt of country including the localities mentioned was at one time favorable to a vigorous and varied vegetable growth.

At a number of localities the same flora occurs, carrying well preserved leaf impressions, together with silicified trunks of trees still standing firmly planted in the muds and breccias.

The flora from this limited area contains 30 species, of which 18 are new to science. Only 2 of the new species are found in the acid breccias, and only 3 have been collected from the basic breccias. Nine of the species identified are common to both acid and basic breccias. Of the species previously described as occurring elsewhere than in the Park, most of them have a wide geological and geographical distribution, ranging from the Laramie well up through the Miocene. The

following species may be mentioned as characteristic of this horizon: *Platanus montana, Quercus yanceyi, Laurinoxylon amethystenium, Populoxylon wardii.*

For the present this group of plant remains has been provisionally designated the intermediate flora, as according to Professor Knowlton, it possesses many distinct features of its own, yet appears as a transition flora between that of the acid rocks and the flora of the basic breccia which is of later age. This flora has been referred to the Lower Miocene.

Directly to the south of the region where both types of rock occur together, the acid breccias suddenly disappear, and later flows bury everything beneath an enormous mass of basic lava. In the deep ravines cut in the abrupt escarpments along the south and west side of Lamar Valley, lies the famous Fossil Forest of the Yellowstone Park. The ravines or gorges expose to view vertical sections nearly 2,000 feet in thickness across the bedded agglomerates, mud flows, and basalt sheets of these early basic breccias. From the base of the breccias as exposed along the valley, nearly to their summit on the top of Specimen Ridge the beds carry abundant evidences of an extinct fossil flora. They have so far yielded 70 species, more than one-half being new to science and described by Professor Knowlton for the first time. Those species that are identified as belonging to both the acid and basic breccias are mainly such species as have a wide geological distribution.

This flora Professor Knowlton regards as distinctly different from that of the acid breccias, and of much later age. In the identification of species and in its affinities it bears a close resemblance to the flora of the Auriferous Gravels of California. It has been referred to the Upper Miocene period, and named the Lamar flora. The following species are selected as characteristic of the Lamar horizon: *Platanus guillelmæ, Laurus californica, Magnolia spectabilis, Planera longifolia, Magnolia culveri, Aralia whitneyi.*

The flora presents many of the same general characteristics throughout the 2,000 feet of beds, which were derived wholly from eruptive material. It has been found impossible as yet to discriminate between the flora of the lowest beds and those at the top. This would indicate much the same climatic and physical conditions during the entire time required for the accumulation of such a mass of volcanic material with its accompanying flora buried beneath successive layers of tuffs and muds. That there were long periods of rest during the piling up of this material is evident from the great size of the trees, whose trunks are still standing at different elevations in the lavas.

On both sides of the Yellowstone, stretching from Crescent Hill to Junction Butte, occur several isolated exposures of an acid lava, remnants of a much more extensive body, the greater part of which has been carried away by erosion. Along the Yellowstone Valley denudation of the overlying material has been so excessive that the relations of these acid rocks to other igneous rocks are somewhat obscure. In many instances it would be impossible to make out their geological position, as they lie completely isolated from other lavas. In some instances they have been preserved from erosion by cappings of basalt, but the age of these basalt flows is by no means identical. They have been grouped together and designated trachytic-rhyolite, from certain resemblances in mineral composition to both these types of igneous rocks, although it can not be stated definitely that they all belong to the same period. For the present they have been correlated as being contemporaneous in age, and are regarded by the writer as of later age than the series of early acid and basic breccias.

As regards their geological relations to other eruptive masses and the general sequence of lavas, they play an unimportant part, and for the purposes of the present paper, which deals more especially with the age and duration of volcanic energy in this region, they are of slight interest, being limited in amount, covering small areas, and carrying no evidences of a fossil flora.

Resting directly upon the irregular surfaces of the early basic breccias comes a succession of distinctly bedded basalt flows, which in places have attained an aggregate thickness of nearly 1,000 feet. They cap several of the higher ridges of the Absaroka Range, and on the west side of the Lamar Valley west of the Range, they present a grand escarpment forming the abrupt wall of Mirror plateau. From this plateau the basalts stretch southward and eastward, sharply defining the series of early acid and basic breccias from later accumulations of igneous rocks. These basalts have been designated early basalt flows, as they mark a distinct period in the geological history of the volcanic eruptions, although flows of basalt frequently occur in the older breccias.

Following these early basalts comes a second series of acid and basic breccias similar in mode of occurrence, mineral composition, and in the varying manifestations of the different phases of eruptive energy. Apparently the centers of volcanic action moved southward and the later series of acid and basic breccias built up the western portion of the southern half of the Absaroka Range. Unlike the early acid breccias, the late acid breccias are not so deeply buried beneath the more recent lavas, but form the tops of several high peaks, and cover large

areas along the summit of the range. The late basic breccias buried in great part the late acid breccias, and in turn built up the extreme southern end of the Absaroka Range, or at least that portion lying within the limits of the Yellowstone Park. The basic breccias stretch southward far beyond the boundaries of the park, and constitute the top of the Wind River plateau, which serves to unite the Wind River and Absaroka Ranges. In places the late basic breccias are shown in precipitous cliffs, exposing a thickness of over 2,000 feet of volcanic material. Unlike the early acid and basic breccias, neither the late acid nor basic breccias have as yet yielded any valuable contribution to our knowledge of an extinct flora. Fragments of silicified wood are common enough, but as yet no bed of tuffs or fragmental material has been found to carry a well-preserved flora. Occasionally fragmental impressions of stems, twigs, and leaves have been collected, but they are too poor for specific identification and of no special significance for comparative purposes. It may be said that the Absaroka Range has nowhere as yet afforded any important plant-bearing beds, the localities furnishing the material lying to the westward of the range.

Penetrating both the late acid and basic breccias, and consequently of later age, occurred extensive outflows of hornblende-mica-andesite. As these dense rocks withstand atmospheric agencies better than the underlying breccias, they often form the summit of isolated peaks in the more elevated portions of the range. These hornblende-mica-andesite flows denote a distinct period in the phases of volcanic phenomena in the Absaroka Range.

After the cessation of volcanic energy which built up the vast pile of andesitic and basaltic breccias and flows, a long period of erosion followed. An enormous amount of material was swept away. Broad valleys and deep canyons were carved out and the present mountains outlined somewhat as they appear to-day. Then with renewed activity volcanic eruption again broke out and immense masses of rhyolite were ejected. These rhyolite flows changed the depressed basin lying between the mountains which surround the Park into an elevated plateau, the lavas accumulating to a thickness of nearly 2,000 feet. The appellation of Park Plateau has been given to this striking physical feature which embraces an area not less than 50 miles in length and 40 miles in width. On all sides the lower slopes of the pre-existing ranges were buried beneath rhyolite, and in some instances the deeply eroded valleys in the andesitic breccias of the Absaroka range were partially filled by the later rock. Underlying the rhyolite at one or two localities occur limited flows of basalt and

again thin interbedded sheets of basalt are found in the upper portion of the rhyolite, but in general the great body of rock presents a singularly uniform mass over the entire plateau. Nowhere have any aqueous deposits or accumulations of detrital material between successive flows been recognized. Neither have any marked evidences of erosion or long intervals of comparative rest been observed during the pouring out of these rhyolites. Although no plant remains or invertebrate fossils have as yet been obtained associated with the rhyolites of the park, they have been referred on other evidence to the Pliocene period.

Along the abrupt wall of the grand canyon of the Yellowstone, just north of Tower Creek, occurs a bed of coarse conglomerate, made up of Archean and andesitic material. On the west side of the canyon the conglomerates rest directly upon andesitic breccias. On both sides of the canyon the conglomerate is overlain by basaltic flows in which columnar structure is well developed. In the conglomerate on the west wall, and directly beneath the overlying basalt, a few vertebrate remains have been collected, which, though fragmentary, were sufficient to enable Prof. O. C. Marsh to determine them as belonging to the skeleton of a fossil horse of Pliocene time. A careful search of the canyon conglomerate failed to find any pebbles of rhyolite mingled with the other material, showing conclusively that none was present in the immediate region when the conglomerate was deposited, as the configuration of the drainage basin is such that had any rhyolite been present, evidences of it would have been detected in the waterlain material. The basalt on both sides of the canyon is covered by rhyolite, a portion of the great rhyolite field in all probability belonging to the earlier flows of this period.

After the cessation of the rhyolite came the final phase of volcanic activity, the pouring out of the recent basalts. They occur along the northern and western boundaries of the Park, skirting the outer edges of the rhyolite mass, where in broad, but comparatively thin, sheets they overlie the former rock. They are admirably shown in the region of Bunsen Peak and Gardiner River but are best developed in Falls River basin, stretching far westward into Idaho in somber, monotonous beds. Occasionally dikes of basalt penetrate the rhyolite, as shown in the escarpment of Madison canyon, but in the broad central portion of the Park plateau outflows of basalt are entirely wanting, even near such a powerful center of eruption as the Sheriden volcano. Upon the cessation of these recent basaltic outflows, after a long period of activity, eruptions of igneous rock in this region came to an end. That this activity lasted throughout the greater part of Pliocene time seems well

established, but there is no evidence of its continuance into the Pleistocene. Slight outbursts of lava may have reached the surface at different times after the coming in of the Pleistocene, but there is no direct evidence that such was the case. If they did break out they were limited in extent and were only evidences of continued internal heat, such as is shown by the hydrothermal phenomena for which this region is still so celebrated.

The facts brought together here clearly demonstrate that the pouring out of igneous rocks began with the post-Laramie uplift or closely followed it, and from the time of the first appearance of these rocks, volcanic eruptions continued with greater or less energy throughout Tertiary time. It is evident that from the time of the post-Laramie uplift there was, as shown in the geological history of the region, a succession of events of great importance in the development of the Rocky Mountains, and that each period of this history was characterized by distinct phases of volcanic phenomena. The great value of paleobotany as an aid in determining the age of the geological formations is singularly well illustrated in the region under discussion. At least five distinct and important geological periods are defined by their fossil flora, and four of them are exposed in the Park within a few miles of each other. Along the abrupt west wall of Mt. Everts, the Laramie sandstones contain several species of plants, sufficiently characteristic to determine the Laramie age of the beds. It has been shown that the Livingston formation resting unconformably upon the Laramie carries a distinct flora, well defined from the Laramie below and the Fort Union above.

About ten miles east of Mt. Everts the early acid andesitic breccias contain a varied Eocene flora, referred to the Fort Union formation. At a number of localities within a few miles of Crescent Hill, the breccias afford a special grouping of fossil plants designated as the Intermediate flora, and regarded as more closely related to the Lamar than to the Fort Union flora. They have been referred to the Lower Miocene.

Above these latter beds in a great development of basic breccias occurs a flora referred to the Upper Miocene period. It has been named the Lamar flora, and correlated with the Auriferous Gravels of California, with which it is closely allied.

The following table may serve to bring out more clearly the relationships between the different geological formations and the floras which characterize them:

Formation.	Flora.	Age.
Basic breccia.	Lamar.	Upper Miocene.
Intermediate breccias.	Intermediate flora.	Lower Miocene.
Acid breccia.	Fort Union.	Eocene.
Agglomerates, Waterlain igneous material.	Livingston.	Cretaceous.
Sandstone.	Laramie.	Cretaceous.

In a thin bed of conglomerate exposed by the cutting of the grand canyon of the Yellowstone, vertebrate remains of a fossil horse were discovered, sufficient to determine the Pliocene age of the deposit. Upon this conglomerate rests the great body of rhyolite and the still later basalt. Soon after the dying out of these recent basalts climatic conditions changed and the Yellowstone Park was covered by glacial ice which distinctly marked the coming in of Pleistocene time.

ART. LI.—*On the Occurrence of Pollucite, Mangano-Columbite and Microlite at Rumford, Maine;* by H. W. FOOTE.

DURING the spring of 1885, Mr. E. M. Bailey of Andover, Maine, sent to Prof. S. L. Penfield for identification some specimens from Black Mountain, Rumford, Me. Among these, one which had the appearance of ordinary white quartz or beryl proved to be the very rare and interesting mineral pollucite. The following summer, the locality was visited by Professor Penfield accompanied by Mr. Bailey and a supply of pollucite and its associated minerals was obtained.

The minerals occur in a ledge of coarse pegmatite which has been worked without success for gem tourmalines, but the locality is of unusual mineralogical interest and the work has been continued to some extent for specimens. In addition to quartz, feldspar and muscovite, which are crystallized on a large scale, there were found pink, green and white tourmalines in imbedded crystals, pink lepidolite, both granular and in crystals, with hexagonal outline, spodumene occasionally in crystals but usually only in cleavage masses, amblygonite rather abundant and in cleavage masses only, beryl not very common, cassiterite rather abundant as irregular masses and rarely in small but distinct crystals, black columbite, pollucite and, very rarely, mangano-columbite and microlite.

Pollucite.

Pollucite has previously been found in the United States at Hebron, Me., where it was discovered by Mr. Loren B. Mer-

rill while mining for gem tourmalines. A full description of this occurrence together with an analysis and a discussion of the chemical composition of the mineral has been given by Prof. H. L. Wells.* The material at Hebron was all found as loose pieces in two cavities, while at Rumford, which is about thirty miles north of Hebron, it is found intimately associated with quartz, albite, muscovite, tourmaline, lepidolite and spodumene. The specimens are not very attractive in appearance as neither the pollucite nor the associated minerals, with the exception of tourmaline, occur well crystallized. The irregular masses of pollucite are sometimes quite large, so that, for example, for a distance of ten centimeters there will be continuous pollucite. Small particles of the mineral are colorless and perfectly transparent, but the masses look as if they had been crushed and the appearance is therefore white. The quartz at the locality is mostly smoky so that it is readily told from the pollucite at a glance, but some of it is quite white, and then it is almost impossible without physical or chemical tests to distinguish the two minerals apart. A great deal of credit is due to Mr. Bailey for having observed that the pollucite was something different from quartz, which needed investigation.

Although occurring in masses of considerable size, the pollucite is not very abundant, but it is hoped, now that the mineral has been identified, that it will be more carefully looked for and saved. It is possible and even quite probable that pollucite is not at all a rare mineral at the tourmaline and lepidolite localities in Maine, but has been overlooked as it resembles quartz so closely and does not occur in characteristic crystals.

Material for a chemical analysis was separated in a very pure condition by means of the potassium mercuric iodide solution. That which was used for the analysis ranged in specific gravity between 3·029 and 2·938, a difference of 0·091. Wells gives 2·986 and 2·976 for the mineral from Hebron. The method of analysis was as follows:

The substance was digested with strong hydrochloric acid for several hours until completely decomposed. The silica and alumnia were then determined in the usual manner. The filtrate from the alumnia precipitation was evaporated to dryness and ammonium salts driven off with extreme caution. The chlorides of the alkalies were dissolved in very little hydrochloric acid and enough lead chloride added to combine with all the cæsium to form the salt Cs_2PbCl_6.† Chlorine was then passed into the hot solution which was

* This Jour. III. xli, p. 213, 1891.
† Ibid., xlvi, p. 186, 1893.

gradually cooled, finally with ice. This operation removed nearly all the cæsium, which was filtered on a Gooch crucible, washed with hydrochloric acid saturated with chlorine, dried at 100° and weighed as Cs_2PbCl_6. The filtrate was evaporated to dryness, the residue taken up in water, the lead removed with hydrogen sulphide and the potassium and remaining cæsium precipitated and weighed as platinum chlorides. The platinum was then determined, from which the potassium and cæsium were calculated. Lithium and sodium were freed from platinum and separated with amyl alcohol. Only a trace of rubidium could be detected by the spectroscope.

Water was determined by strong ignition of the substance over a powerful blast lamp.

Following are the results of the analyses, together with the analysis of the mineral from Hebron, by Wells:

	I.	II.	Average.	Ratio.		Hebron.
SiO_2	43·75	43·54	43·64	·727	9·00	43·51
Al_2O_3	16·77	16·90	16·84	·165	2·03	16·30
Cs_2O	36·25	36·03	36·14	·128		36·10
K_2O	0·33	0·42	·037	·004	·168 2·07	·48
Na_2O	2·06	2·11	2·09	·033		1·68
Li_2O	0·03	0·13	0·08	·003		·05
H_2O	1·57	1·59	1·58	·082	1·01	1·50
						CaO=0·22
	100·76	100·72	100·74			99·84

The results of the analyses are remarkably close to those obtained by Professor Wells and the ratio which is nearly 9:2:2:1 gives the formula $H_2Cs_4Al_4(SiO_3)_9$ as deduced by him.

In a recent article, "On the Constitution of the Silicates,"* Clarke has discussed the constitution of pollucite and considered two formulæ, one, $H_2Cs_2Al_2Si_5O_{15}$, deduced from the analysis of the mineral from Elba by Rammelsberg, the other that of Wells, The latter had shown, however, very conclusively that his formula was correct and that it agreed better with the results of the earlier analysis than did that of Rammelsberg, and this new analysis fully substantiates his view.

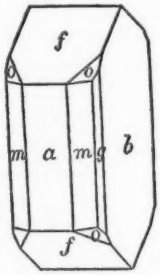
Many thanks are due Professor Wells for his many helpful suggestions as to methods of analysis.

* Bull U. S. Geolog. Survey, No. 125, p. 31, 1895.

Mangano-Columbite.

This mineral is found in imbedded crystals which are seldom over 10^{mm} long. The color is a dark reddish brown, very closely resembling that of rutile. The available material was not sufficient for a quantitative analysis, but a qualitative examination showed the the presence of manganese, tantalum and niobium. A specific gravity determination on 0·3242^{gr} of material taken very carefully on a chemical balance gave 6·44, which would indicate a chemical composition about midway between a niobate and tantalate and near that of the mangano-columbite from Branchville, analyzed by Comstock.*

1.



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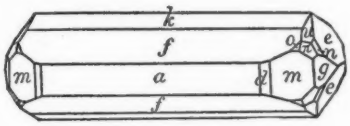

The crystals show a considerable variation in habit, being usually prismatic in the direction of the *c* axis, fig. 1, sometimes lengthened parallel to *a*, fig. 2, while occasionally they are about equally developed in all directions. They show a very good cleavage parallel to *b*, 010. The forms which were observed are similar to those found on columbite and are as follows:

a, 100	*m*, 110	*f*, 102	*u*, 133
b, 010	*g*, 130	*e*, 021	*π*, 121
d, 730	*k*, 103	*o*, 111	*n*, 163

They gave a few excellent reflections which served to establish the lengths of the crystallographic axes. The values are given below, together with the axes for columbite as determined by E. S. Dana.†

	Mangano-Columbite.	Columbite.
$m \wedge m$,	$110 \wedge 1\bar{1}0 = 79° 47'$	79° 17′
$f \wedge f$,	$102 \wedge \bar{1}02 = 55\ 40$	56 28
	$\breve{a} : b : \dot{c} = 0{\cdot}8359 : 1 : 0{\cdot}8817$	0·8285 : 1 : 0·8898

The variation in the ratios is undoubtedly due to a change of both acid and base, the measurement by Dana having been

* This Journal, xix p. 131, 1880. † Zeitschr. Kryst. xii, p. 266, 1886.

made on columbite from Standish, Me., having a specific gravity of 5·65, and which according to the analysis of Allen* contains only a little tantalum and manganese.

Several forms gave rather unsatisfactory reflections. Some of the measured and calculated angles are as follows:

		Calculated.	Measured.	Calculated for Columbite.
$f \wedge f'$,	$102 \wedge \bar{1}02 =$	55° 40′	55° 40′*	56° 28′
$k \wedge k'$,	$103 \wedge \bar{1}03 =$	38 47	38 52	39 23
$d \wedge d'''$,	$730 \wedge 7\bar{3}0 =$	39 25	39 56	39 6
$m \wedge m'''$,	$110 \wedge 1\bar{1}0 =$	79 47	79 47*	79 17
$g \wedge g'''$,	$130 \wedge 1\bar{3}0 =$	136 31	136 51	136 10
$g \wedge g'$,	$130 \wedge \bar{1}30 =$	43 29	44 5	43 50
$e \wedge e'$,	$021 \wedge 0\bar{2}1 =$	120 57		121 20
$m \wedge o$,	$110 \wedge 111 =$	36 0½	35 55	35 38
$o \wedge o'$,	$111 \wedge \bar{1}11 =$	76 44		77 29
$o \wedge o'''$,	$111 \wedge 1\bar{1}1 =$	62 30½		62 27½
$\pi \wedge \pi'$,	$121 \wedge \bar{1}21 =$	55 0	55 3	55 30
$\pi \wedge \pi'''$,	$121 \wedge 1\bar{2}1 =$	101 2		100 59
$n \wedge n'$,	$163 \wedge \bar{1}63 =$	19 42		19 54
$n \wedge n'''$,	$163 \wedge 1\bar{6}3 =$	118 0		118 20
$u \wedge u'''$,	$133 \wedge 1\bar{3}3 =$	79 32		

One variation from columbite shown by the habit of these crystals is that the form *f*, which is the predominating one at the termination of all of the crystals, is of rare occurrence and has previously been observed only with slight development on columbite.

Microlite.

Very beautiful crystals of microlite averaging 2^{mm} in diameter of a honey-yellow color and high luster are found sparingly at the locality. The prevailing form is the octahedron, modified by the dodecahedron and sometimes by the icositetrahedron, 113. The habit is then very much like that of the pyrochlore figured on page 762 of the sixth edition of Dana's Mineralogy. The specific gravity, taken by Professor Penfield on 0·2642 gr. of material was found to be 5·17, which is somewhat low for microlite and due probably to the presence of a little more niobium than usual. A qualitative analysis indicated the presence of calcium and of tantalum in considerable excess over niobium.

In closing, I wish to express my thanks to Professor Penfield for his kind assistance during the entire investigation and to Mr. Bailey for a generous supply of the rare and interesting minerals from this locality.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, New Haven, November, 1895.

* Zeitschr. Kryst., xii, p. 272, 1886.

Art. LII.—*A Device for Simplifying the Drawing of Crystal Forms;* by A. J. Moses.

In a former article* I described a graphic method for obtaining any axial cross from any projection of the isometric axes by use of a quadrant and scale; any axial length, sine or cosine being measured on the scale and quadrant and laid off on the vertical axis and the proportionate length obtained on any other line through the center by connecting the ends and drawing a line parallel to the connecting line from the point on the vertical axis. Necessarily the vertical axis was either the length of the radius of the quadrant or proportionate dividers were used.

The method is made still simpler by laying off all measurements upon a "scale line" drawn at will from the centre of the axial cross and of a length equal to the radius of the quadrant and by using a metal quadrant shown in fig. 1, the center of

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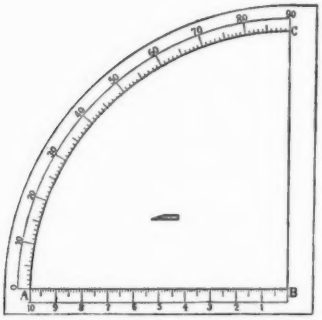

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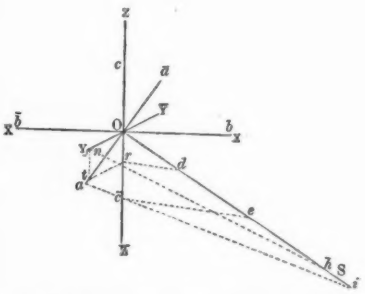


which is at B. The edge AB and the arc AC are tapered to a thin edge for greater exactness in marking. With AB ten centimeters long the results will be correct within the limits of a drawing.

Axial lengths are transferred directly from AB to the scale line approximately to the third decimal. Sines and cosines are transferred as follows. If the edge BC and the scale line are made coincident and then, by use of a triangle, the quadrant is slid along in a direction at right angles thereto (BC remaining parallel to the scale line) until the scale line cuts the arc at the given degree and approximate minute, the intercept on the scale line will be the sine. Similarly with the edge AB coincident with the scale line and a motion at right angles thereto, the intercept on the scale line will be the cosine.

* School of Mines Quarterly, xv, 214–218.

All measurements are transferred to other lines, as above described, by lines parallel to the direction between the ends of the scale line and the unit line. The device can also be used in the measurements needed in obtaining edge directions.

Fig. 2 represents the construction of the axial cross of a monoclinic crystal in which $a : b : c = 1{\cdot}092 : 1 : 0{\cdot}589$ and $\beta = 74° 10'$. XX YY ZZ is the isometric axial cross; OS is the scale line. O*h* is sine 74° 10′ when radius is OS and transferred to OY is O*n*; O*d* is cosine 74° 10′ when radius is OS and transferred to OZ is O*r*; by completing the parallelogram *t* and O*t* result. For the axial lengths, O*i* is 1·092 times OS and O*e* is 0·589 times OS and transferred are respectively $Oa = 1{\cdot}092 \times Ot$ and $O\bar{c} = 0{\cdot}589 \times OZ$.

Munich, March 16, 1896.

Art. LIII.—*Concerning Crookes Tubes;* by C. C. Hutchins and F. C. Robinson.

We would offer the following contribution to the rapidly increasing literature on the X-rays of Röntgen. It has to do with a part of the subject upon which very little has been written, and for that reason may be helpful to other experimenters.

One of the chief difficulties in the way of experimenting has been the cost of the bulbs or tubes. We have proved to our own satisfaction that the making of them need not be beyond the resources of the ordinary laboratory; for within a few weeks time we have made and tested more than one hundred tubes, and have frequently made one and exhausted it and used it, all within an hour's time. All that is required is some little skill in glass-blowing and in the manipulation of the pump.

The glass.—A hard German glass, or its equivalent, free from lead, has proved the best. It gives a strong green fluorescence under the action of the current, and what is of great importance, resists without softening the heat generated by the cathode ray at its point of impact. Unfortunately it is not to be had free from bubbles, and these are the cause of the destruction of many tubes; the glass being chipped away into the bubble by the action of the current and the tube ruined. It is also rather difficult to put in the electrodes so that they will stay, and it may be necessary to use three kinds of glass,—first

the tube itself, then a bit of softer glass, and upon that very soft lead glass for the seal.

Shape of the tube.—A good tube should throw shadows as sharp as possible and develop the rays as powerfully as possible. It should easily appear that the ordinary spherical form meets neither of these conditions.

To produce a sharp shadow the radiant must be small. It was found that a picture could be taken upon any side of a spherical bulb; making it probable at least that the entire surface is a source of radiation.

In the matter of strong action also, the spherical form is inferior. This is for two reasons:—first, glass more or less extinguishes the rays according to its thickness, therefore, the larger the bulb the more opaque it must be, for it must be thick enough to stand the atmospheric pressure.

Secondly: there is a comparatively large amount of radiant or conducting matter within the spherical bulb which diffuses the energy of the discharge.

Proof of the second point was obtained as follows. A moderately thick bulb about three inches in diameter was blown, and upon this a spot one inch across was blown out very thin, forming a smaller hemispherical bulb upon the first. Opposite this thin window was the concave cathode. This bulb proved better than the ordinary sort, but far inferior to tubes about to be described. A second experiment was made with a tube blown thin along one side for a space of three inches, and opposite this was the cathode in the form of a quarter cylinder. The performance of this was also inferior.

Without going into the details of many similar experiments, it will be sufficient to say that we have found that a simple straight tube from one-half to one inch in diameter, having a small and very thin bulb for a cathode window, has given the most satisfactory results. In length it may be from four to eight inches. The bulb may be blown at the bottom of the tube, the cathode placed at the top, and the anode across the tube just above the bulb. Better results are, however, produced by using a bit of platinum foil for an anode, inclining it about forty-five degrees to the cathode ray. In this case the small bulb may simply be blown out upon the side of the tube and the electrodes put in at the two ends, so that the cathode ray will be reflected into the bulb.

Shape and disposition of the electrodes.—We have made the cathode in the form of a wire, a flat plate, a convex plate and a concave plate. The concave form proves the best in every case. We have made it of varying size, up to an inch or more in diameter, and have not come to any conclusion as to which

is best. It is very difficult to have other conditions sufficiently uniform to enable one to judge, where differences are small.

We have made the anode in the form of a wire of aluminum, a flattened strip of it, and, as stated above, in the form of a platinum reflector. As yet we have got our best results from the platinum. One rather interesting result obtained was, that when the anode was in the form of an aluminum disc parallel to the cathode and nearly large enough to close the tube, it gave little or no interference with the X-ray. We made one on a hinge so that it could be swung out of the path of the ray or in at pleasure, and the effect on the photographic plate was the same in either position.

Source of the rays.—Being able to construct tubes of any form, we have made many experiments as to the source of the rays, whether from the cathode or anode. One was in this way:—Two tubes were joined together parallel so that they were exhausted together. The cathode rays could be made to pass down one tube and the anode rays (if such existed) down the other, and either screened off at will. We found that the anode rays affected the plate but slightly, and that practically all the effect came from the cathode.

Intensity of effect.—We do not intend to convey the impression that these home-made tubes we have described are simply good enough for experiment and valuable from their cheapness. We believe also that they are more effective than others. We have made good negatives of bones of the hand, arm, including the elbow, foot, ankle, etc., all with remarkably short exposures; have taken impressions perfectly distinct through nine inches of wood in less than five minutes; have taken perfectly the bones of the hand through thin sheet zinc in two minutes and through the slide of the plate holder in five seconds. The ordinary coin and key impression require not over one or two seconds with our best tubes.

Remarks upon pumping.—The interest in the subject at present may make some remarks upon pumping here in place, most of all, since many have found great difficulty in this respect.

It is here supposed that the pump has a three-way cock above its bulb, opening in its two positions between the bulb and fork and the bulb and outer air; and that above this three-way cock are one or two cocks of the ordinary kind. Let the three-way cock be called A, the others B and C in order. Let the position in which A puts the bulb in communication with the fork be position 1; and that in which it puts the bulb in connection with B, C, and the outer air, position 2. The ordinary process of pumping with the use of A alone is supposed to be understood. After a greater or less number of

strokes it is observed that no more air is obtained. The pump contains air, however, condensed upon the glass walls. To remove this A is put in position 2, and the mercury raised until a drop passes B. B is then shut and the mercury dropped until only a drop remains above A. A is then shut and the movable mercury tank dropped to its lowest point, when A is put in position 1. Pumping now goes on as before only with B shut, and the tank is raised only a third as high as before. After four or five strokes it is well to pass the mercury again above B.

If the highest possible degree of exhaustion is desired this process can be repeated between B and C, but this is not necessary in exhausting a Crookes tube.

As soon as the stage of pumping with B shut is reached, the tube which is being exhausted must be strongly heated, moving the lamp flame over every part of it, and after two or three strokes more the current from the coil is turned into the tube. By the combined action of the heat and current the occluded air is driven from the glass and exhaustion proceeds rapidly. It should not occupy over twenty or thirty minutes for a moderate sized tube.

Allowing the tube to cool, if short sparks can be drawn from the bulb and there is little or nothing to be seen in it except green light, the exhaustion is complete. There is danger of carrying it too far, for the vacuum very much increases during the first hour that the tube is used; but of these matters a little experience is the best teacher.

Searles Science Laboratory, Bowdoin College, May 6, 1896.

Art. LIV.—*Researches on the Röntgen Rays;* by Alfred M. Mayer.

Contents: *1. The Röntgen rays cannot be polarized by passing through herapathite. 2. The density of herapathite. 3. The formulæ of transmission of the Röntgen rays through crown glass, aluminum, platinum, green tourmaline and herapathite. 4. The actinic action of the Röntgen rays varies inversely as the square of the distance of the sensitive plate from the source of the rays.*

1. The Röntgen rays cannot be polarized by passing through herapathite.

Herapathite is an iodo-sulphate of quinine, discovered by W. B. Herapath in 1852,* and named herapathite by Haidinger. Herapath gives several formula for its production. The one which succeeded the best with me in giving crystal plates of large area is contained in Phil. Mag., Nov. 1853. It is as follows:

Bisulphate of quinine	3·24 grams.
Pyroligneous acid	56^{cc}
Alcohol (95 per cent)	56^{cc}
Solution of iodine (1 grm. in 11^{cc} alcohol)	50 drops.

The bisulphate of quinine is added to the mixture of pyroligneous acid and alcohol and heated to 55° C., and then the iodine is added drop by drop while constantly stirring the solution. The vessel containing the solution is then placed on several layers of thick felt resting on a firm support to prevent vibration, and it thus remains about 18 hours at a temperature of 8° C. At the expiration of that time large crystals will generally be seen floating on the surface of the liquid, the majority being at the bottom of the vessel. The solution gives, of herapathite, only $\frac{1}{15}$ of the weight of bisulphate of quinine.

As suggested by Herapath, a microscope cover glass is cemented to the end of a glass rod, with its plane at right angles to the rod, and is carefully brought under the floating crystal, very slowly brought up to it and the crystal is thus secured on the surface of the glass. The mother liquid is then absorbed from the glass by blotting paper. If several crystals are desired on a cover glass, a glass tube closed by the finger is brought over the crystals at the bottom of the vessel, the finger removed, then replaced and the tube taken out of the liquid. The crystals are allowed to sink into the drop at the end of the tube by holding the latter for some time in a vertical position;

* Phil. Mag., Mar. 1852

the drop is then brought in contact with a cover glass. This is the manner in which I placed on the glass discs and blotting paper the plates of herapathite used in my experiments.

Röntgen has shown that generally the lower the density and always the thinner the substance the less it screens from a photographic plate the action of the X-rays. Herapathite is, therefore, eminently fitted as *the* substance on which to make experiments which are to decide whether the X-rays can or cannot be polarized by having traversed crystals which, like herapathite and tourmaline, transmit only one polarized beam, the other being absorbed by the crystal, for the density of herapathite is 1·557 and plates of only ·012^{mm} thick are sufficient to answer the question. When crystals of herapathite ·012^{mm} thick have their optic axes crossed at 90° these crossed portions viewed against incident light appear black, so powerful is the polarizing property of this substance. If the X-rays be polarizable these black portions should act like thick lead and completely screen the sensitive film from the action of the X-rays. The fact is that the crossed herapathites do not screen the X-rays any more than the herapathites do when superposed plates have their axes parallel. In the latter case the crystals freely transmit light with a faint olive-green tint.

The thickness of crystal plates used in the experiments varied from ·01^{mm} to ·025^{mm}, as found by focussing with a micrometer-screw a powerful objective on the top surface of the crystals and on the glass on which they rested.

Six discs of glass, ·15^{mm} thick and ·25^{mm} in diameter, were covered with herapathites in the manner described. They crossed one another at various angles; where they crossed at 90° the crossed portions were black. On a piece of yellow blotting paper, $\frac{3}{4}^{mm}$ thick, were also placed several layers of herapathites, so deep that they reflected a green metallic luster like the elytra of cantharides. These discs and the blotting paper were fastened to the slide covering the photographic plate. This slide was impervious to two hours' exposure to the actinic action of the sun's light. On the slide were also three discs of thin glass, so overlapping that the X-rays had to pass through 1, 2, 3 thicknesses of the glass before reaching the sensitive plate. These served as standards with which to compare the screening effects of the herapathites.

The slide so prepared and covering a sensitive plate was exposed to the radiations of a Crookes tube in three experiments, for $\frac{1}{2}$, 1, and $2\frac{1}{2}$ hours. On developing the plates, not the slightest trace of the presence of the herapathites was visible. The photographs of the glass discs had not the slightest mottling on their surfaces; appearing to the unaided eye and when examined through a magnifying glass with uniform illu-

mination and grain throughout, and exactly like the photograph obtained by the X-rays passing through a similar glass disc with nothing on its surface. The herapathites used in the experiments were so thin that they did not appreciably screen the X-rays, whether the axes of the superposed crystals were parallel or crossed. But the action of the rays on the square of blotting paper proved even more conclusively that the X-rays cannot be polarized in this manner, for where this paper covered the photographic plate nothing was visible, except by careful scrutiny and with a favorable illumination, and then a mere ghost of the paper was detected, but with no traces whatever of the herapathites.

These experiments confirm in a convincing manner what Röntgen found by his experiments, viz: that the X-rays cannot be polarized. At least, they cannot be polarized by passing through herapathite, which is by far the most powerful polarizing substance known. It is unlikely that polarization will be detected by using any doubly refracting substance which transmits two beams polarized in planes at right angles to each other; for if polarization exist, the thickness of the substance required to get a measurable departure of the two rays so screens the X-rays that a very small fraction of them (at least by calcite) will be transmitted; also, Röntgen is of the opinion that if the X-rays be refrangible, the index of refraction is nearly unity even in such a highly refracting substance as ebonite, which has an index of about 1·6.* It is therefore reasonable to suppose that the difference in the refraction of the ordinary and extraordinary beams will be too small to be measurable in the faint shadowgraphs obtained by traversing doubly refracting substances.

It remains to be decided whether the X-rays can or cannot be polarized by reflection, Professor Rood having recently proved conclusively that they are reflected from platinum.

2. The density of herapathite.

Herapath gives 1·89, at 60° F., as the density of the very remarkable substance he discovered.† As its density is interesting to have in connection with the experiments described above, I made two determinations of it by weighing about ·3 grs. of the substance in water, and also by the displacement it gave of the water in a specific gravity flask. The mean of these two measures was 1·6. As this

* On the Physical Properties of Vulcanite, by A. M. Mayer, this Journal, Jan. 1891.

† Phil. Mag., May, 1855, p. 369.

number differs greatly from that of Herapath, I thought that the small mass I had used was the cause of the discrepancy. I then made about two grams of herapathite, freed it of its mother liquid by washing with water at 0°, and dried it at 25° in vacuo. When it had ceased to lose weight I weighed it in a specific gravity flask holding about 10 c.c., then just covered it with water, placed it in vacuo and agitated it, so that it would be freed of any air that might be contained in its mass. The flask was then nearly filled with water and again placed in vacuo, then entirely filled and weighed. I found from this carefully made experiment that the density of herapathite is 1·557 at 20° C.

3. The formulæ of transmission of the Röntgen rays through glass, aluminum, platinum, green tourmaline and herapathite.

The Röntgen rays, after their transmission through various substances, produce actinism on a photographic plate, and by the degree of this actinism we have attempted to obtain the formula of transmission peculiar to each substance. This action of the X-rays is cumulative and evidently is entirely different from the transmission of light and radiant heat where the maximum of transmission is instantly reached and under proper and controllable conditions remains constant and therefore can be accurately measured. But with the X-rays the amount of their action on the plate varies directly as the time of their action (see 4), depends on the distance of the sensitive plate from source of radiation, and on the energy of the source. Therefore this method of determining the constants of the formulæ of transmission of the X-rays is somewhat arbitrary; but the exact conditions in the determination of the constants having been given, these conditions can readily be obtained by other experimenters. Thus, to have the same conditions as existed in our experiments, one has only to place a pile of crown glass plates 5·5^{mm} thick, at such a distance from the radiant source that on two hours exposure the X-rays will have just not visibly acted on the photographic plate. Some assumption has to be made as to the nature of the X-rays, otherwise no progress can be made in determining the constants of their formulæ of transmission. We have assumed that they are homogeneous. The formulæ, as determined, hold good till they have conclusively been shown not to be homogeneous, which is very likely to happen in the progress of research on their nature.

The method used owes whatever merit it may have to the use of the wire netting devised by Professor Rood to give accurate indications of the relative permeability of various

substances to the X-rays. This wire netting he places on the slide covering the sensitive plate, and on the netting he places substances of various thickness. The netting completely screens the X-rays, and its image on the negative is the brightest possible to obtain in the given conditions. If a plate of a substance should also entirely screen the X-rays, then the image of the netting is invisible in the photograph of this substance, and as plates of substances allow more and more of the X-rays to traverse them the images of the netting in the photographs of these substances are more and more bright. If the image of the netting in the photographs of two substances should be equally bright, then these two plates transmit equal actinic action to the sensitive plate. Thus this ingenious device serves as a very delicate photometer in determining the fact just mentioned.

It occurred to me that the wire netting could also give me data with which to determine the constants of the formulæ of transmission of the X-rays through various substances. The method devised is as follows: On a wire netting with 8 meshes to the inch placed on the slide of the plate-holder, are cemented piles of glass discs, (each glass about $\frac{1}{10}^{mm}$ thick); these piles gradually increase in thickness. These piles of glass were exposed to the action of the X-rays, so that the photographic plate was 25^{cms} distant from the radiant source. In the apparatus used this distance could be accurately measured. After an exposure of two hours it was found, on developing the plate, that the netting was *just visible* in the photograph of the pile $5{\cdot}35^{mms}$ thick, and that it was not visible in the photograph of the pile $5{\cdot}5^{mm}$ thick. In this last case, though the X-rays had penetrated to the sensitive film, yet the difference in the screening effect of the netting and of the glass was not visible, because the eye cannot distinguish between the illumination of juxtaposed surfaces which differ in illumination by about $\frac{1}{100}$. Hence, through the last pile of $5{\cdot}5^{mm}$ about $\frac{1}{100}$ of the actinic intensity of the incident beam had passed.

Now the formula of transmission of rays through a substance which does not reflect these rays is $I' = Ia^t$. Where $I' =$ the intensity of the transmitted beam; $I =$ the intensity of the incident beam; $a =$ a constant depending on the substance, and t is an exponent of a, and t is the thickness of the substance. We have taken $\frac{1}{10}^{mm}$ as the unit of t.

From the conditions of the experiment $I' = Ia^t = \frac{1}{100}$, and as t is known, a is readily computed. The accuracy of the determination of a depends on the value of the least perceptible difference in illumination that the eye can distinguish in two juxtaposed surfaces. We have adopted $\frac{1}{100}$ as the most probable value.* But suppose that the fraction is not $\frac{1}{100}$ but

* Photometric Experiments, O. N. Rood, this Journal, July 1870.

$\frac{1}{115}$, or, $\frac{1}{88}$, then the departure of these fractions from $\frac{1}{100}$ will affect the constant by 4 units in the third decimal place.

These experiments, made in the conditions we have indicated, give for the formula of transmission through the glass used, a crown glass made by Chance & Co.:

$$I' = I \times \cdot 92^t$$

Having this formula as a basis, it is comparatively easy to determine the constants of another substance, by placing the substance on the netting with piles of glass of graded thickness and exposing them to the X-rays. We then see what thickness of glass gives the same illumination to the image of the netting as does the known thickness of the substance. Thus, the netting in the photograph of a disc of herapathite $\cdot 9^{mm}$ thick had the same brightness as in the photograph of a pile of glass $\cdot 69^{mm}$ thick. By the formula glass $\cdot 69^{mm}$ thick transmits $\cdot 5636$ of the incident beam and herapathite of $\cdot 9^{mm}$ transmits the same. From this we compute that $I' = I \times \cdot 9382^t$ is the formula for the transmission of the X-rays through herapathite, which for $t = \cdot 69$ gives $\cdot 5636$ of transmission.

In the same manner it was found that

$2 \cdot 05^{mm}$	of	aluminum	transmits	the	same	as $2 \cdot 44$	of glass
$\cdot 02$	"	platinum	"	"		$2 \cdot 9^{mm}$	"
$2 \cdot 0$	"	green tourmaline	"	"		$2 \cdot 0$	" "
$\cdot 69^{mm}$	"	herapathite	"	"		$\cdot 9$	" "

From these determinations we have computed the formulæ of transmission of these substances:

Glass	$I' = I \times \cdot 92^t$
Aluminum	$I' = I \times \cdot 905^t$
Platinum	$I' = I \times \cdot 00063^t$
Green tourmaline	$I' = I \times \cdot 92^t$
Herapathite	$I' = I \times \cdot 938^t$

Taking the amount of transmission through aluminum of $\frac{1}{10}^{mm}$ and of 1^{mm} as unity, we have, in the following table, the relative transmission through the substances experimented on.

	$t = \frac{1}{10}^{mm}$.	$t = 1^{mm}$.
Aluminum	1·	1·
Glass	1·016	1·180
Green tourmaline	1·016	1·180
Herapathite	1·036	1·435
Platinum	·000696	

Platinum $\cdot 06^{mm}$ thick is practically impervious to the rays from the Crookes tube used, transmitting only $\cdot 005$ of incident beam.

This method of determining the transmission of the X-rays through various substances may be criticised, because in the experiments I obtain not alone the transmission through the

substances placed on the slide of the plate-holder but at the same time the transmission through the slide itself. If the slide has a measurable transmission, or, screening effect, then its equivalent in thickness of the substances placed on it should be added to them. This criticism, however, is nought, because experiments have shown that if the thickness of a portion of the slide is doubled by placing on it a piece of the material of which it is made, no screening of the X-rays by this piece can be detected.

4. The actinic effect of the Röntgen rays varies inversely as the square of the distance of the sensitive plate from the radiant source.

The slide covering a photographic plate had on it the wire netting, and the plate was exposed for 30 minutes to the X-rays at a distance of 10 inches from the radiant source. Another similar plate in the same plate-holder was exposed for two hours at a distance of 20 inches from the radiant source. These distances could be accurately measured in the apparatus used. These plates were taken from the same box and developed side by side in the same tray. Indeed all the conditions were carefully made the same in the two experiments except the distance of plates from the radiant source. On developing the images on the plates they were exactly alike; the image of the netting had the same illumination on each plate, and the density of the films was the same. This experiment shows that the X-rays act on a sensitive plate according to the law of the inverse squares.

From this law it follows that the actinic power of the X-rays is not sensibly absorbed in traversing the air; also, that these rays are not sensibly diffused by radiation from the molecules of the air they traverse, the air being at ordinary barometric pressures.

These deductions, which necessarily follow from the law of the inverse square, are, however, at variance with the facts observed by Professor Pupin, who states in Science of April 10, 1896: "There was evidently a diffuse scattering of the X-rays in their passage through the air." . . . . . "These experiments prove beyond all reasonable doubt that the Röntgen radiance is diffusely scattered through bodies, gases not excepted." These opinions of Professor Pupin are founded on experiments on the action of the X-rays on a fluorescent screen, or, rather on a "fluoroscope," not on experiments on their actinic effects. In the latter case I am confident that the X-rays act according to the law of the inverse squares, and therefore are not sensibly diffused. In the former case Professor Pupin finds that they are diffused in traversing the air, and very sensibly diffused if I understand aright his

paper; but as he does not give any photometric measures, or estimates, of the intensity of the fluorescence in the geometric image of the slit, and outside of this image, one cannot form an opinion of the amount of the diffusion he describes. The facts of diffusion described by Professor Pupin are opposed to those discovered by so distinguished and experienced a physicist as Röntgen, who, in section 10 of his first paper, writes: "I find, using a Weber's photometer, that the intensity of the fluorescent light varies nearly as the inverse squares of the distance between screen and discharge tube. This result is obtained from three very consistent sets of observations at distances of 100 and 200^{mm}. Hence air absorbs the X-rays much less than the cathode rays. This result is in complete agreement with the previously described result, that the fluorescence of the screen can be observed at 2 metres distance from the vacuum tube." Röntgen does not mention any diffusion observed by him in these experiments, and it is certain that he would have mentioned the existence of diffusion in experiments made to determine a law of radiation, and which diffusion necessarily would have invalidated the law of inverse squares.

The radiation from the Crookes tube, used in the experiments described in this paper, came from a calcined shell supported by the anode wire and placed opposite the cathode. The tube was not sensibly heated during the experiments and the actinic power of its radiation remained constant. It was proved by taking a pin-hole photograph of the naked tube, with an exposure of two hours, that by far the larger proportion of the X-rays emanated from a 4^{mm} square surface of the shell which was acted on by the cathode rays. The walls of the glass tube, as was proved by other independent photographic experiments, furnished a small percentage of X-rays but not enough to make their presence known in the pin-hole photograph, which had furnished quite a dense image of a portion of the shell. Furthermore the X-rays from the glass wall itself were cut off and prevented from reaching the photographic plate by a diaphragm of lead with a circular opening of one-half inch, and at one inch distant from the radiant source. It is also to be remarked that this second source of the X-rays was nearer to the photographic plate only by $\frac{7}{10}$ inch minus ·06 inch, the thickness of the tube, hence any effects due to them may be neglected, as indeed the results in the experiments on the inverse squares show.

The experiments described in this paper were made in the private laboratory of Professor Rood in Columbia University. Professor Rood not only gave me the use of his apparatus, which he had made the subject of a special investigation before investigating with it, but he also gave me the advantage of the experience obtained during his researches on the X-rays.

ART. LV.—*On the* PITHECANTHROPUS ERECTUS, *from the Tertiary of Java;* by O. C. MARSH.* (With Plate XIII.)

NEAR the beginning of last year, a discovery was announced that excited great interest throughout the scientific world, especially among those interested in the origin and antiquity of man. The announcement first made was that remains of a veritable missing link between man and the higher apes had been found in Java, in strata of Pleistocene age. The discovery was made by Dr. Eugène Dubois, a surgeon in the Dutch army, who had been stationed in Java for several years, and had devoted much time to the vertebrate fossils of that island.

The first definite information received in this country was in December, 1894, when Dubois's memoir on *Pithecanthropus* arrived.† One of the first copies reached the late Professor Dana just as he was printing the last pages of his great work on geology. He at once wrote to me in Washington, asking me to look up the memoir, and telegraph my opinion of the discovery, so that he could refer to it in his book. On inquiry, I ascertained that this memoir had not then been received at any of the scientific centers in Washington, and that the discovery itself was not known. On returning to New Haven, I found a copy of the memoir awaiting me (received December 29, 1894), and at Professor Dana's request, I wrote a review of it, which appeared, with illustrations, in this Journal for February, 1895.‡

The memoir of Dr. Dubois was an admirable one, and, although written in Java, with only limited facilities for consulting the literature on the subject and for comparing the remains described with living and extinct forms to which they were related, the author showed himself to be an anatomist of more than usual attainments, and fully qualified to record the important discovery he had made. In my review, therefore, of this important memoir, I endeavored to state fairly the essential facts of the discovery, as well as the main results reached by Dr. Dubois after a careful study of the remains.

* Abstract of communication made to the National Academy of Sciences at Washington, April 24, 1896.

† *Pithecanthropus erectus.* Eine menschenaehnliche Uebergangsform aus Java. Von Eug. Dubois, Militairarzt der niederlaendisch-indischen Armee. Mit zwei Tafeln und drei in den Text gedruckten Figuren. 4to, Batavia, 1894.

‡ The figures then given in Plate II are repeated in the plate accompanying the present article.

My own conclusions in regard to this discovery, briefly stated in my review, were as follows:—

"It is only justice to Dr. Dubois and his admirable memoir to say here, that he has proved to science the existence of a new prehistoric anthropoid form, not human indeed, but in size, brain power, and erect posture, much nearer man than any animal hitherto discovered, living or extinct. . . . . Whatever light future researches may throw upon the affinities of this new form that left its remains in the volcanic deposits of Java during later Tertiary time, there can be no doubt that the discovery itself is an event equal in interest to that of the Neanderthal skull.

"The man of the Neander valley remained without honor, even in his own country, for more than a quarter of a century, and was still doubted and reviled when his kinsmen, the men of Spy, came to his defense, and a new chapter was added to the early history of the human race. The ape-man of Java comes to light at a more fortunate time, when zeal for exploration is so great that the discovery of additional remains may be expected at no distant day. That still other intermediate forms will eventually be brought to light no one familiar with the subject can doubt."

In most scientific quarters, however, both in this country and in Europe, Dr. Dubois's discovery was not received with great favor, and the facts and conclusions stated in his memoir were much criticised. Among a score or more of notices of this elaborate memoir which appeared subsequent to my review, I do not recall a single one that, in attempting to weigh the evidence presented, admitted the full importance of the discovery made by Dr. Dubois. The early conclusions seemed to be that the various remains discovered were human, and of no great age; that they did not belong to the same individual; that the skull apparently pertained to an idiot; and that both the skull and femur showed pathological features. In fact, the old story of the distrust aroused by the discovery of the Neanderthal skull, nearly forty years before, was repeated, although in a milder form. Dr. Dubois has stated in a late memoir that, with the exception of Professor Manouvrier of Paris and myself, no one else, until very recently, regarded the remains as evidence of a transitional form between man and the apes.

It was a fortunate thing for science that the Dutch government appreciated the importance of the discovery made in its Javanese province by Dr. Dubois, and last summer allowed him to return to Holland and bring with him the precious remains he had found, and so well described. Not only this,

2.

P Hs

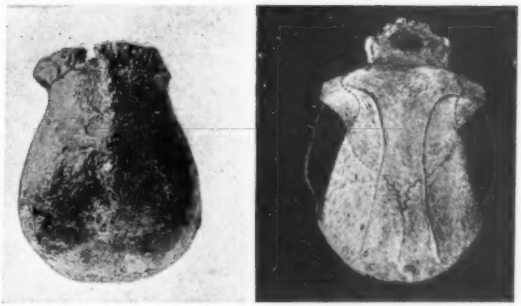


FIGURE 2.—P. Cranium of *Pithecanthropus erectus*, $\frac{1}{6}$.
Hs. Skull of *Hylobates syndactylus*, $\frac{1}{3}$. (After Dubois.)

5.

P H

a *b* *a* *b*

FIGURE 5.—P. Left femur of *Pithecanthropus erectus*, $\frac{1}{6}$.
H. Left femur of man, $\frac{1}{6}$. (After Dubois.)
a, front view; *b*, exterior view.

but he was also permitted to bring the extensive collections of other vertebrate fossils which he had secured from the same horizon and in the same locality where the *Pithecanthropus* was discovered. All these were shown at the International Congress of Zoologists, held at Leyden, in September last, and on the 21st of that month, Dr. Dubois read an elaborate paper on his original discovery and on his later explorations in the same region. This communication was in many respects the most important one of the session, and its presentation with the specimens themselves was a rare treat to the large audience present, especially to those fitted to appreciate the evidence laid before them.*

Professor Virchow of Berlin was president of the meeting on that day, and had brought many specimens to illustrate the remarks he was to make in the discussion. The famous Leyden museum was also drawn upon for an extensive series of specimens of man and the higher apes, so that, if possible, the true position of *Pithecanthropus* might then be determined once for all. Dr. Dubois, moreover, kindly invited Professor Virchow, Sir William Flower, and myself, to come an hour before the meeting, and personally examine the remains he was to discuss, and this invitation was most gladly accepted.

The first sight of the fossils was a surprise, as they were evidently much older than appeared from the descriptions. All were dark in color, thoroughly petrified, and the matrix was solid rock, difficult to remove. The skull-cap of *Pithecanthropus* was filled with the hard matrix, firmly cemented to it. The roughness of the superior surface, especially in the frontal region, was apparently due to corrosion after entombment, and not to disease, as had been suggested by some anatomists. The femur was free from matrix, but very heavy in consequence of the infiltration of mineral matter. The exostosis on its upper portion is a conspicuous feature, but of course is pathological. This feature is of little consequence, as very similar outgrowths occur on fossil bones of even Eocene age. The two teeth showed no characters that indicated their interment under circumstances different from that of the skull or femur. All the physical characters impressed me strongly with the idea that these various remains were of Pliocene age, and not Post-Tertiary, as had been supposed. The description of the locality and the account of the series of strata there exposed, as given by Dr. Dubois in his communication, confirmed this opinion, and a later examination of accompanying vertebrate fossils placed the Pliocene age of all beyond reasonable doubt.

* Compte-Rendu des Séances du Troisième Congrès International de Zoologie, Leyden, September, 1895, pp. 251–271. 1896. See also Transactions Royal Dublin Society, vol. vi, pp. 1–18, February, 1896; and Anatomischer Anzeiger, Bd. xii, pp. 1–22, 1896.

The facts relating to the discovery itself, and the position in which the remains were found, as stated by Dr. Dubois in his paper, together with some additional details given to me personally, convinced me that, in all probability, the various remains attributed to *Pithecanthropus* pertained to one individual. Under the circumstances, no paleontologist who has had experience in collecting vertebrate fossils would hesitate to place them together.

In figure 1, below, a geological section is given, showing the series of strata exposed in the bank of the river Bengawan, near Trinil, in central Java, where all the remains of *Pithecanthropus* were found. The exact positions of these various specimens when discovered are also indicated.

1.

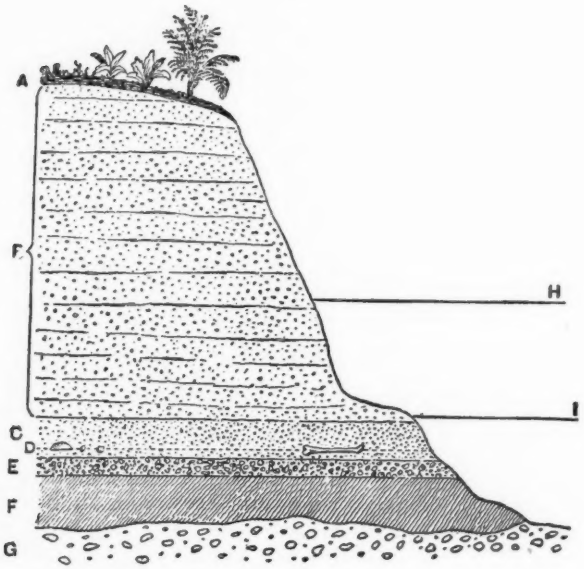


FIGURE 1.—Section of the bone strata at Trinil. (After Dubois.)
A, vegetable soil; B, sand-rock; C, bed of lapilli-rock; D, level in which the four remains were found; E, conglomerate; F, clay-rock; G, marine breccia; H, rainy season level of river; I, dry season level of river.

The above section, taken from Dr. Dubois's Dublin paper, makes clear many points as to the locality where the discoveries were made, which were left doubtful in the original memoir.

The three specimens originally described, the tooth, the skull, and the femur, were found at different times in the same horizon, all imbedded in the same volcanic tufa, as indicated in figure 1, D. The tooth was found first, in September, 1891, in the left bank of the river, about a meter below the water level during the dry season, and twelve or fifteen meters below the plain in which the river had cut its bed. A month later, the skull was discovered, only a meter distant from the place where the tooth lay. In August, 1892, the femur also was found, about fifteen meters distant from the locality where the other specimens were imbedded. Later, in October of the same year, a second molar was obtained at a distance of not more than three meters from where the skull-cap was found, and in the direction of the place where the femur was dug out.

The fossils thus secured were all carefully investigated by Dr. Dubois, who regards them as representing a distinct species and genus, and also a new family, which he has named the *Pithecanthropidæ*, and distinguished mainly by the following characters:

Brain cavity absolutely larger, and, in proportion to the size of the body, much more capacious than in the *Simiidæ*, yet less so than in the *Hominidæ*. Capacity of the skull about two-thirds the average of that of man. Inclination of the nuchal surface of the occiput considerably greater than in the *Simiidæ*. Dentition, although retrogressive, still of the simian type. Femur equal in its dimensions to that of man, and like that adapted for walking in an upright position.

Of this skull, the upper portion alone is preserved, the line of fracture extending from the glabella backward irregularly to the occiput, which it divides somewhat below the upper nuchal line. The cranium seen from above is an elongated oval in outline, dolichocephalic; and is distinguished from that of other anthropoid apes by its large size and its higher arching in the coronal region, as shown below in figure 3. The greatest length from the glabella to the posterior projection of the occiput is 185^{mm}. The greatest breadth is 130^{mm}, and the smallest, behind the orbit, is 90^{mm}. The cranium in its original condition must have been of somewhat larger dimensions. The upper surface of the skull is without ridges, and the sutures all appear to be obliterated.

This dolicocephalic skull, with an index of 70°, is readily distinguished from that of the Orang-utan, which is decidedly brachycephalic. The absence of the characteristic cranial crests will separate it from the skull of the adult Gorilla. In its smooth upper surface and general form, it shows a resemblance to the skull of the Chimpanzee, and still closer to that of the Gibbons (*Hylobates*).

A figure of the present specimen and the skull of a Gibbon for comparison are shown in figure 2, Plate XIII. These figures and those that follow are reproduced from illustrations in Dr. Dubois's memoirs.

In comparing the cranium of *Pithecanthropus* with skulls most nearly allied, both human and simian, the outlines given in figure 3, below, will prove especially instructive. The basis of this cut is the figure given by Dr. Dubois in his Leyden paper. This I have modified by omitting the outline of the microcephalic idiot, and substituting that of the well-known Neanderthal skull.*

3.

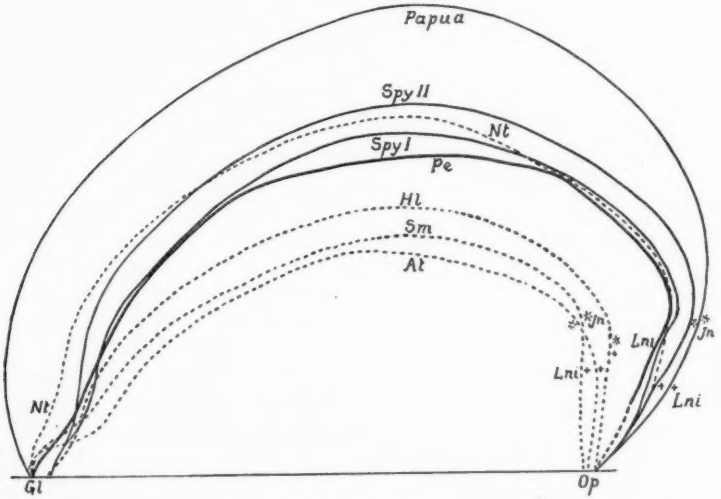


FIGURE 3.—Profile outline of the skull of *Pithecanthropus* (*Pe*), compared with those of a Papuan man, the man of Spy No. 1, Neanderthal man (*Nt*), man of Spy No. 2, and *Hylobates leuciscus* (*Hl*), *Semnopithecus maurus* (*Sm*), and *Anthropopithecus troglodytes* (*At*). (Modified from a figure by Dubois.)

Gl, glabella; *Op*, opisthion; *Jn*, linea nuchæ superior; *Lni*, linea nuchæ inferior.

Dr. Dubois's conception of the skull of *Pithecanthropus*, when entire, is indicated by his attempted restoration shown in figure 6, on page 481. Future discoveries must determine the accuracy of this restoration.

* In presenting the present paper before the National Academy of Sciences at Washington. I was fortunately able to exhibit a cast of the *Pithecanthropus* skull, recently sent to me by Dr. Dubois, and also to compare this with a cast of the Neanderthal skull. The latter was not available during the discussion at Leyden.

The tooth, the first specimen found, is represented in figure 4, below. It is the last upper molar of the right side, and is in good preservation. It indicates a fully adult, but not very old, animal. The crown is subtriangular in form, with the corners rounded, and the narrowest portion behind. The antero-posterior diameter of the crown is 11·3^{mm}, and the transverse diameter 15·3^{mm}. The grinding surface of the crown is concave, and less rugose than in existing anthropoid apes. The diverging roots are a simian feature.

4.

FIGURE 4.—Third right upper molar of *Pithecanthropus erectus*. Two-thirds natural size. (After Dubois.)
a, back view; *b*, top view.

6.

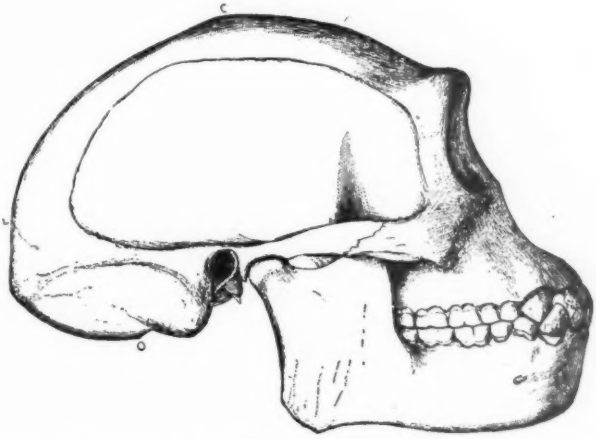


FIGURE 6.—Restoration of the skull of *Pithecanthropus erectus*. Two-fifths natural size. (Reduced from a figure by Dubois.)
C, sutura coronalis; L, sutura lamboidea; O, foramen occipitale.

The femur, which is from the left side, is in fair preservation, although it was somewhat injured in removing it from the surrounding rock. It belonged to a fully adult individual. In form and dimensions, it resembles so strongly a human femur that only a careful comparison would distinguish one

from the other. The bone is very long, its greatest length being 455^{mm}. The shaft is slender and nearly straight. The general form and proportions of this femur are shown in figure 5, Plate XIII, with a human femur for comparison.

These various remains of *Pithecanthropus* were again described in detail and compared with allied forms by Dr. Dubois in his paper at Leyden, and in the discussion that followed, the whole subject was once more gone over by anthropologists, zoologists, and geologists, in a most thorough and judicial manner. To attempt to weigh impartially the evidence as to the nature of *Pithecanthropus*, presented by Dr. Dubois in his paper and by those who took part in the critical discussion that followed its reading, would lead far beyond the limits of the present communication. I can only say that this evidence was strongly in favor of the view that the skull of *Pithecanthropus* is not human, as the orbital and nuchal regions show, while at the same time it indicates an animal much above any anthropoid ape now known, living or extinct. Opinions differed as to whether the various remains pertained to the same individual, but no one doubted their importance.

The varied opinions expressed in regard to the anatomical characters of each of the specimens have already been published, and need not be repeated here. Dr. Dubois, in his papers above cited, has met all the principal objections made to his views since he announced his discovery. He has also given full references to the literature, which promises to be voluminous as the importance of the subject becomes better known. Among the authorities thus cited may be mentioned Cunningham, Keith, Lydekker, Turner; Manouvrier, Pettit, Topinard, Verneau; Haeckel, Krause, Martin, Ten Kate, and Virchow, who have all taken part in the discussion.

After a careful study of all the *Pithecanthropus* remains and of the evidence presented as to the original discovery, the position in which the remains were found, and the associated fossils, my own conclusions may be briefly stated, as follows:

(1) The remains of *Pithecanthropus* at present known are of Pliocene age, and the associated vertebrate fauna resembles that of the Siwalik Hills of India.

(2) The various specimens of *Pithecanthropus* apparently belonged to one individual.

(3) This individual was not human, but represented a form intermediate between man and the higher apes.

If it be true, as some have contended, that the different remains had no connection with each other, this simply proves that Dr. Dubois has made several important discoveries instead of one. All the remains are certainly anthropoid, and if any of them are human, the antiquity of man extends back into the Tertiary, and his affinities with the higher apes become much nearer than has hitherto been supposed. One thing is certain: the discovery of *Pithecanthropus* is an event of the first importance to the scientific world.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The molecular weight of sulphur.*—Previous investigations have shown that the sulphur molecule probably corresponds to the formula S_8, or to S_6, at a temperature slightly above its boiling point, and that as the temperature rises the molecular weight becomes smaller, until between 860 and 1700° it is constant and corresponds to a normal molecule, S_2. Previous work upon the molecular weight of sulphur in solution, as determined by the boiling-point and the freezing-point methods, has in most cases pointed to the formula S_6. Orndorff and Terrasse have now described an elaborate series of experiments in which the boiling-point method has been used with various solvents, and they conclude from their results that at temperatures below its melting-point the molecule of sulphur is S_8, while with solvents whose boiling-points are above the melting-point of sulphur, the molecular formula is S_8. The interesting fact was observed that when dissolved in sulphur chloride (S_2Cl_2) the molecule of sulphur corresponds to the normal formula, S_2. The authors have also made the observation that in carbon disulphide, from which only orthorhombic sulphur crystallizes out, and in benzene and toluene, from which the monoclinic form alone separates, the same molecule, S_8 exists.—*Am. Chem. Jour.*, xviii, 173. H. L. W.

2. *The absorption of the Röntgen rays by chemical compounds.*—Novák and Sulc have examined nearly 300 substances in this respect. Their method of investigation consisted in attaching rings of glass to a sheet of paper and placing uniform layers of the finely pulverized materials in the different rings so that the thickness of the layer was 0·4^{cm} in each case. The paper with the rings was then placed over a photographic plate which was enveloped in black paper, and exposed to the Röntgen rays for a period of 20 to 25 minutes. By comparing the photographic effect of the rays where the substances were interposed, the relative absorptions were determined. The authors found that a great number of organic compounds containing only carbon, hydrogen, oxygen and nitrogen, are equally penetrable, and hence they conclude that the absorption has no relation to molecular weight or the arrangement of the atoms. Organic halogen derivatives were found to possess much greater absorption, which increased with the number of halogen atoms present. This effect increased with the atomic weights of the halogens, two atoms of bromine having a greater effect than six chlorine atoms, while iodine derivatives were entirely impenetrable under the conditions used in the experiments. This indication of the influence of elements of varying atomic weight led the authors to examine a series of elementary substances, all of rather low atomic weights. The absorptive power was as follows:

$$\underset{32}{S}=\underset{31}{P\beta}>\underset{27}{Al}>\underset{24}{Mg}>\underset{11}{B}=\underset{12}{C\alpha}(=Air).$$

This series agrees in a striking manner with the order of the weights of the atoms, and the metallic or non-metallic character of the substance seems to be without influence. Salts of different metals with the same acid showed a variation, in like manner, with the atomic weights:

$$\underset{}{NH_4}<\underset{7}{Li}<\underset{23}{Na}<\underset{39}{K}<\underset{85}{Rb}$$

also,

$$\underset{9}{Be}<\underset{24}{Mg}<\underset{40}{Ca}<\underset{87}{Sr}<\underset{137}{Ba}$$

The calcium salts are almost equal to the potassium salts, while the strontium and rubidium salts are also nearly alike, thus showing the influence of almost identical atomic weights.

Salts of different acids with the same metal also formed regular series:

Carbonate<Nitrate<Sulphate<Chloride<Bromide<Iodide.
Chlorate<Bromate<Iodate.
Phosphate<Arsenate, etc.

With compound radicals it seems as though the absorptive power depended upon the average atomic weights of the component atoms. For example, ammonium, NH_4, $\frac{14+4}{5} = 3{\cdot}6$, gives less absorption than lithium. This view is in harmony with the easy penetrability of organic compounds composed of the elements C, H, O and N of low atomic weight.—*Zeitschr. Physikal. Chem.*, xix, 489. H. L. W.

3. *A Dictionary of Chemical Solubilities, Inorganic;* by A. M. Comey, 8vo, pp. 515 (Macmillan & Co., 1896, price $5).—More than thirty years have elapsed since the appearance of Storer's Dictionary of Solubilities, and Professor Comey has rendered a valuable service to chemists in writing a modern work upon this subject in such an excellent manner. The author has aimed to include all analyzed inorganic compounds, so that the book is a compendium which will serve a purpose in inorganic chemistry similar to that of Beilstein's "Handbuch" in the organic domain. The full references to the literature make the work especially valuable. The typographical work is admirable, but we think that a word of protest should be entered against the uncut "tops," especially for a dictionary. H. L. W.

4. *Les Fermentations*, par P. Schützenberger, 8vo, pp. 314, Paris 1896 (Félix Alcan).—In presenting this, the sixth edition of his work on fermentation, to the public, the eminent author has entirely re-written the book and has placed it in harmony with the present condition of the science. It is divided into two parts, the first treating of direct fermentation, produced by organisms, the second part being devoted to soluble ferments, or indirect

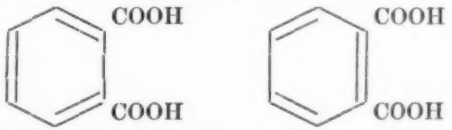
fermentation. The work gives a clear and accurate survey of this very interesting and important department of chemistry.

H. L. W.

5. *Répertoire des Réactives Spéciaux*, par F. JEAN et G. MERCIER, 12mo, pp. 121, Paris 1896.—This little book gives the formulæ for preparing special chemical reagents which usually bear the names of the originators. The main arrangement is alphabetical according to the names of the authors, while another alphabetical list is given of the substances to be detected. More than four hundred reagents are included, and the book will doubtless be a convenience to all practical analysts. The value of the work would have been considerably increased if references to the original articles had been given. H. L. W.

6. *The existence of two Orthophthalic Acids.*—Considering the great amount of work that has been done with orthophthalic acid by various chemists, the recent discovery by W. T. H. HOWE, that this compound exists in two isomeric modifications, seems remarkable. The two acids are identical in composition, molecular weight and molecular refraction, but they differ (1) in melting-points, (2) in electrical conductivity, (3) in solubility, (4) in the properties of their salts, and (5) in their reduction-products. The melting-points of the two acids, when finely pulverized, are 184°, and 203°. The lower melting acid is converted into the higher simply by boiling the aqueous solution for several hours. The reverse change takes place by boiling a solution in 30 per cent. sodium or potassium hydroxide for some time and precipitating the acid from the cold solution by means of hydrochloric acid.

The author is inclined to explain the isomerism by a change in the arrangement of the single and double bonds in Kekulé's benzene ring, as is shown in the following diagrams:



This establishment of a case of two isomeric ortho-derivatives of benzene has an important bearing upon the theory of the structure of the benzene nucleus, for the previous lack of well-established cases of such isomerism has been considered to be a strong argument against Kekulé's celebrated ring formula in its original form.—*Am. Chem. Jour.*, xviii, 390. H. L. W.

7. *On the nature of the X-rays.*—D. A. GOLDHAMMER states his reasons for believing that the X-rays are ordinary transverse waves of light of which the wave-length are much smaller than the hitherto observed ultra violet rays. Röntgen concluded that the effect observed by him was not due to ultra violet light from the following:

a. The X-rays suffer no observable refraction in passing from air into water, bisulphide of carbon, aluminum rock salt, glass, zinc, etc.

b. They are not regularly reflected by known bodies.

c. They are not polarized by ordinary means.

d. Their absorption depends only on the factor of thickness of absorbing layer.

According to the author, the absence of observed reflection could be due to a wave-length extremely small in comparison with the inequalities of even highly polished surfaces. The absence of polarization can also be explained by similar reasoning ; *b* and *c* are thus explained. The behavior of the new rays toward metals and other substances is compared with the behavior of certain solutions like fuchsin, and aniline toward ordinary light. In the case of fuchsin solutions the absorbtion is proportional to the concentration. If we compare Röntgen's results on the effect of thickness of layers on the rays, with the absorption of fuchsin, one is led to believe that the thickness of bodies plays the role with X-rays of the concentration of fuchsin solutions for ordinary light. Prisms filled with fuchsin solutions give anomalous refraction and dispersion, is it not possible that the bodies investigated by Röntgen exhibit anomalous dispersion? By means of anomalous refraction and dispersion *a* and *d* can thus be explained. With rays of extremely short wave-length, the absorption fitness of bodies may be mainly determined by their thickness. It is possible that the X-rays are present in the arc spectrum of platinum or lead.—*Ann. der Physik und Chemie*, No. 4, 1896, pp. 635–638. J. T.

8. *Recent work with Röntgen Rays.*—*Nature*, April 30, 1896, has a résumé of this work. Dr. A. Winkelmann and Dr. R. Straubel (Jena) have investigated the refraction of the Röntgen rays and by using prisms of various metals obtained in each case a value of about 1 : 0·0038 referred to air. Professor Rhigi and Drs. A. Fontana and A. Umani (Rome) find that the radiation from a Crookes tube does not effect the radiometer in any way. Various observers have determined the relative opacity of different substances. Professor E. Doelter of Graz finds (1) that the opacity of minerals does not always increase with the density, although minerals having a specific gravity greater than 5 are relatively opaque ; (2) that the complexity of the chemical constitution of a mineral effects its opacity, but no general law of relationship can be enunciated; (3) dimorphous minerals exhibit but slight differences in their behavior with regard to the rays in their different forms; (4) in most crystals, the amount of absorption does not depend sensibly on the direction of the incident rays; (5) all minerals naturally fall into about eight well-defined groups, corundum, talc, quartz, rock salt, Iceland spar, etc. The diamond is ten times as transparent as corundum and 200 times as transparent as tin foil. Dr. Filippo Campanile and Dr. Emilio Stromei (Naples) have succeeded in obtaining Röntgen rays from ordinary Geissler tubes. A variety of new forms of Crookes tubes have been invented. Professor Elihu Thomson has devised a double focus tube for use with a Thomson or Tesla coil. Both

terminals consist of aluminum mirrors. The rays impinge upon a V-shaped reflector of platinum which is placed in the middle of the tube. The effects obtained with this tube are very remarkable. I have been able to trace the outline of the heart and of the liver and to see all the ribs. The shadow of the hand can be seen through two oak doors at a distance of fifteen feet; and sensitive plates are fogged through brick walls a foot thick at a distance of fifteen feet. It has been found possible to construct tubes which are much better able to stand the strong excitation of a Tesla coil than hitherto. J. T.

9. *Diminution of the intensity of Sound with the distance.*—Various attempts have been made to determine the diminution of the intensity of sound with the distance especially by Vierordt and by Wien. The former experimented with the sound produced by weights falling on plates from different heights. He reached the result, that the sound diminished according to a linear relation with the distance. Wien measured the diminution of the sound intensity by means of determination of the amplitude—and stated the law that the intensity of sound diminishes with the square of the distance—the law is modified by frictional resistances. KARL L. SCHAEFER takes up the question anew, by the following method. A watch is placed at a certain distance from one ear and a telephone excited by a suitable interrupter is placed at a certain distance so as to just overcome the slightest ticking of the watch. Then the observation is repeated with a different position of the telephone and from a combination of the observations, it was seen that Vierordt's results were unreliable. The sound intensity in the neighborhood of the telephone diminishes more slowly than the square of the distance. With increasing distance the diminution increases, until the quadratic diminution is approximately reached and afterwards even exceeded.—*Ann. der Physik und Chemie*, No. 4, 1896, pp. 785–792. J. T.

II. GEOLOGY AND NATURAL HISTORY.

1. *Fifteenth Annual Report of the United States Geological Survey.*—This report has just been delivered by the Public Printer. It is a handsome volume of 755 pages and 48 plates, and contains, besides the administrative reports of the Director himself and of chiefs in charge of work, the following special papers: "Preliminary Report on the Geology of the Common Roads of the United States," by Prof. N. S. Shaler; "The Potomac Formation," by Prof. L. F. Ward; "Sketch of the Geology of the San Francisco Peninsula," by Andrew C. Lawson; "Preliminary Report on the Marquette Iron-bearing District of Michigan," by Prof. C. R. Van Hise, W. S. Bayley, and H. L. Smyth; and "The Origin and Relation of Central Maryland Granites," by C. R. Keyes, with an "Introduction on the General Relations of the Granitic Rocks in the Middle Atlantic Piedmont Plateau," by the late Prof. G. H. Williams.

From these titles it is evident that the paper of most popular interest is the first one, on roads, by the versatile Harvard professor. He treats of the history of American roads, the methods of using stone in road-building, the relative value of road stones, their distribution, sources of supply, etc.; and thus makes a timely contribution to a subject which is receiving special attention in all parts of the country.

This is the last report made by Major J. W. Powell as Director of the Survey, who until recently has had charge of the work, under different organizations, for twenty-five years.

2. *Topographical maps of the U. S. Geological Survey;* CHAS. D. WALCOTT, director.—The following sheets of the topographical maps of the edition of 1895, are published and ready for distribution:

The San Francisco sheet, Cal.; Bryon, S. Dak.; Alpine, Tex.; Chispa, Tex.-Mex.; Dayton, Wyo.; Aberdeen, S. Dak.; Laramie, Albany Co., Wyo.; Bodreau, La.; Marfa, Tex.; Hickory, N. C.; Ocala, Fla.; Fort Ann, Vt.; Panasoffkee, Fla.; Aspen, Col.; White Hall, N. Y.-Vt.; Wartburg, Tenn.; Ned Lake, Mich.; Perch Lake, Mich.; Amsterdam, N. Y.; Sierra Blanca, Tex.; Williston, Fla.; Nomini, Md.-Va; Sherwood, Tex.; Duluth, Minn.; Tsala Apopka, Fla.; Oriskany, N. Y.; Oneida, N. Y.; Chittenango, N. Y.; Kingfisher, Oklahoma; Willsboro, N. Y.-Vt.; Crawford Notch, N. H.; Tazewell, Va.-W. Va.; Citra, Fla.; Cripple Creek (Special), Col.; Crandall Creek, Wyo.; Ishawooa, Wyo. H. S. W.

3. *A summary Description of the Geology of Pennsylvania.*—This compact summary of the long series of reports of the second Pennsylvania survey is now complete.* The first volume of 719 pages by the state geologist, contains the descriptions of the Laurentian, Huronian, Cambrian and Lower Silurian formations, and the author states in his preface that he has written the report "in Saxon English, for the use of the people of Pennsylvania," in which he has "endeavored to avoid dogmatic statements not made by a consensus of the geological opinion of to-day," and he further describes the book as "almost wholly a practical description of facts discovered and verified by the observation of the members of the corps of the geological survey in their several districts." At the end of the several chapters appear full-page plates of half-sized reproductions of the fossils of the formations considered in the chapter, being reproductions of the figures which originally appeared in report P. 4, Dictionary of the Fossils of Pennsylvania. In volume ii, the upper Silurian and Devonian formations are treated in like manner; and both these volumes were published in 1892, and contain continuously paged 1628 pages.

* "A Summary Description of the Geology of Pennsylvania," in three volumes, with a new geological map of the state, a map and list of bituminous mines, and many page-plate illustrations. J P. Lesley, state geologist, pp. 1–2638, plates 1–611.

Volume iii, part I, was begun by the state geologist, whose health broke down after completing the earlier chapters; the remainder of the work was prepared by Messrs. E. V. d'Invilliers and A. D. W. Smith. This part includes the discussion of the Carboniferous in general. In the second part of vol. iii, the bituminous coal fields are described by M. d'Invilliers, and the New Red of Bucks and Montgomery counties is described by Benjamin Smith Lyman. For the purposes for which these volumes were designed they seem to be admirably adapted, and for scientific students of geology they constitute a very convenient summary of the immense amount of detail of Paleozoic geology developed by the corps of the Second Pennsylvania Geological Survey. Mr. Ingham, the secretary of the Board of Commissioners, has added under separate covers a general index with an appendix containing a list of, and brief guide to, the publications of the survey. H. S. W.

4. *The Geology of the Road-Building Stones of Massachusetts, with some Consideration of Similar Material from other parts of the United States;* by N. S. Shaler; (extract from 16th Ann. Report U. S. Geol. Survey 1894–95, Part II, pp. 277–341.)—Following the more general treatment of the geology of common roads of the United States, which appeared in the 15th Annual Report, Professor Shaler has here given, in his customary clear, terse and vivid manner, a practical account of the nature, mode of occurrence and values for road-making of the rocks found on the surface of Massachusetts. In the section upon tests the author emphasizes the considerable importance of the cementing quality of the fine material produced by the wear of the stone; remarking that the experiments "indicate that it may be desirable in certain cases, when a stone otherwise suitable for macadam purposes does not afford from its powder a good cement, to cover the road with dust made by grinding some other variety of stone which will form a firmer bond." He speaks of the saving of expense in the use of properly selected glacially-distributed bowlders over quarry stone, and estimates that an average of 35 cents per ton may be thus saved in the construction of roads in the State of Massachusetts, amounting in the aggregate to seven million dollars in twenty years. In the Connecticut valley region the finest of all road-metal is found in the "trap" rock of the dikes. The materials available for road-making are discussed primarily under three divisions: i.e., drift-materials, bedded rock and dike and vein stones, and under each of these heads the distribution within the state is noted.

A table of statistics closes the report, concerning the resistance to wear of road-building stones based upon tests made by Mr. L. W. Page, Geologist of the Massachusetts Highway Commission. H. S. W.

5. *The University Geological Survey of Kansas, conducted under authority of the Board of Regents of the University of Kansas;* by Erasmus Haworth and assistants. Vol. 1, pp.

1–320, plates i–xxxi, figures 1–11. 1896.—The plan of committing the execution of the geological survey of states to the geological department of its chief university is excellent in many ways. Not only does it enable those who are likely to be the best fitted for, and most interested in investigating the geology of the state to do the work, but it must result in raising the tone and value of the geological department of the university which carries on the investigation. In organizing the geological survey, Kansas, by act of the legislature in 1889, provided that a geological survey should be one of the functions of the university. In 1893 active work was begun, and in 1895 the board of regents declared the state geological survey organized with the following officers, viz: F. H. Snow, chancellor of the university, *ex-officio* director; in charge of the several departments, Prof. S. W. Williston of paleontology, Prof. Erasmus Haworth of physical geology and mineralogy, and Prof. E. S. Bailey of the department of chemistry. Beginning with the summer of 1893, the professors, assisted by advanced students, made a preliminary survey of the state, and the present report is the result of their labors. The Carboniferous formations of the state have been mapped, classified and named, and the characteristic fossils of each of the formations recorded.

The nomenclature and classification adopted has already been reported in these pages (vol. l, pp. 452–466).

The authors have followed the principle adopted by the U. S. geological survey in giving local names to each of the distinguishable formations, a principle which has the advantage of expressing the facts which the geologist observes and therefore knows, without committing him to a correlation which only the paleontologist can determine after a comparative study of the fossil faunas or floras. The evil of this system is more apt to arise from the limited knowledge of the observer than from any fault in the system itself. New names should be given only where the stratigraphic and structural continuity with formations in contiguous areas already surveyed is not recognizable. For the object to be attained is not to give names to the formations which shall be familiar to the local geologist, but to properly distribute the formations in the standard geological scale. H. S. W.

6. *Geological Survey of Canada.*—The following reports and maps have been recently published, viz:

Summary Report of the Geological Survey Department for the year 1895, by the Director, G. M. Dawson, pp. 154, 1896.

Report on the Surface Geology of eastern New Brunswick, northwestern Nova Scotia and a portion of Prince Edward Island, with maps Nos. 558, 559, 561, 562, 563, by R. Chalmers, pp. 149, 1896.

Report on the Area of the Kamloops map-sheet, British Columbia, with maps, Nos. 556 and 557, by George M. Dawson, pp. 427, 1896.

Laurentian area to the north and west of St. Jerome, Province of Quebec, by F. D. Adams, pp. 20, 1896.

List of Publications of the Geological Survey of Canada, Ottawa, pp. 52, 1895.

Contribution to Canadian Paleontology. Vol. II. Part 1.

Canadian Fossil Insects, Myriapods and Arachnids, by Samuel H. Scudder.

1. The Tertiary Hemiptera of British Columbia.
2. The Coleoptera hitherto found fossil in Canada.
3. Notes on Myriapods and Arachnids found in Sigillarian stumps in the Nova Scotia Coal Field, pp. 66 and plate V. 1895.

7. *Das Tierreich, eine Zusammenstellung und Kennzeichnung der rezenten Tierformen. Herausgegeben von der Deutschen Zoologischen Gesellschaft. Generalredakteur*, FRANZ E. SCHULZE. *Probe-Lieferung—Heliozoa* bearbeitet von FRITZ SCHANDIN. pp. 24 (R. Friedländer & Sohn, Berlin), 1896.—The Deutsche Zoologische Gesselschaft announce their purpose to prepare a comprehensive representation of the whole animal kingdom, naming and giving the characters of every known species now living, or which has in recent times become extinct. About fifty specialists have been selected to prepare the "lieferungs" on the special groups. It is expected that 25 years will be required to finish the work. The publishers (Friedländers of Berlin) have sent out a sample number on the Heliozoa, which is before us. In these 24 pages 59 species are cited, full references to original descriptions and bibliography for species, genera and orders are given, generic descriptions, and brief indications of the distinctive specific characters, and habitat and geographical distribution are given in each case. The systematic part and the publishers' part are also all that could be desired. The first lieferung is announced for the beginning of the year 1897. H. S. W.

8. *The Comparative Morphology of the Galeodidæ*, by H. M. BERNARD. Trans. Linn. Soc., London, 2d ser., vol. vi, part 4, pp. 305–417, plates 27–34, 1896. Few comparative anatomists or morphologists are so suggestive in their teleological discussions as the author of the present paper on *Galeodes*. His first important work on the *Apodidæ*, published in 1892, in which the Crustacea are deduced from a bent carnivorous annelid, has only lately received the recognition it deserves, and, remarkably enough, several inferences made upon theoretical grounds have been fully verified by recent discoveries relating to the ventral anatomy of Trilobites. The adverse criticism which this book first received was entirely uncalled for, and is an instance where dogmatism and autocracy are allowed to take the place of judiciousness. Hostility was incited mainly by its attitude on the "Limulus-an-Arachnid" question, although the work itself was not in the slightest degree polemical.

The *Galeodidæ* are undoubted Arachnids possessing marked primitive characters. They show the original metamerism of the body more strongly than any other Arachnid. The only fused segments are the three anterior cephalothoracic somites. The others are free, including also the ten segments of the abdomen. Therefore, these animals offer inviting opportunities for comparative morphological studies.

Most important and interesting are the discussions on the phylogeny of the Arachnida and their lack of affinity with the Merostomata. An ancestral Arachnid is reconstructed having

eighteen segments, divided into two regions. The anterior portion consists of six segments, which with their appendages are specialized for locomotion and prehension. The posterior region of twelve segments is a vegetative sac. It is shown that the first fusion of segments involved the three anterior ones. In the Arachnids, the first segment was distorted and prolonged dorsally for the purpose of developing the first pair of appendages as powerful prehensile organs; while in the Merostomata, the primitive differentiation occurred through a backward ventral distortion and bending of the first segment.

Considering the mouth as primarily anterior, its ventral position in the Crustacea is the result of modification. *Galeodes* with its anterior mouth is in this respect the most primitive Arachnid, and to develop this type from *Limulus*, the latter "would have to recover its long-lost Annelidan segments almost in their primitive condition, and then, after tilting the first back on to the dorsal surface, further develop this primitive Arachnidan specialization till it reached the Scorpion stage. So that an animal having carried one specialization to an extreme would have to undo it all, in order to try a specialization the exact opposite of its own. I think it fairly safe to say that this is impossible."

A similar reversion and secondary progression would be required to develop the Arachnid sternites out of a Limuloid, or to produce the Arachnid abdomen from the specialized region in *Eurypterus* or *Limulus*. Furthur conclusions of a like nature are drawn from the construction of the beak out of a labrum and labium; from the ocular tubercle, which is unknown in other Arthropods; from the vestigial abdominal limbs, the nervous system, the œsophagus, etc. "They separate the Arachnids completely from all other Arthropods, and furthest of all from *Limulus*, whose essential morphology, or, in other words, whose early differentiation of the primitive ancestral metamerism was the very reverse of that in the Arachnids. As Anthropods, no relation whatever exists between them; as segmented animals however, they are both derivatives from the Chætopod Annelids, but along different and opposite lines of specialization." C. E. B.

9. *The Characeæ of America;* by Dr. T. F. Allen.—The third fascicle of Part II of Dr. Allen's monograph has just appeared and contains descriptions of ten species of Nitella with nine plates. The new species are *N. Leibergii* from Oregon, and *N. transilis*, founded on *N. tenuissima* var. *longifolia* of Allen's Char. Exsic. Amer. There is also a full description and figure of the little known *N. Asagræana* Schaffner from Mexico, and critical notes on several varieties of *N. mucronata*, *N. capitellata*, *N. gracilis* and *N. tenuissima*. W. G. F.

10. *Kryptogamen-Flora von Deutschland, Oesterreich und der Schweiz. Hysteriaceæ, Discomycetes* (Pezizaceæ); by Dr. H. Rehm.—This large volume of more than 1,200 pages, with many figures illustrating the structure of the different genera, is one of the best of the excellent monographs which, taken collectively,

form the second edition of what is generally known as *Rabenhorst's Kryptogamen-Flora.* On the death of Dr. G. Winter, by whom was written the volume including Uredineæ, Ustilagineæ, Basidiomycetes and Pyrenomycetes, the work on the orders of fungi was continued by Dr. Rehm, whose account of the Discomycetes is now completed in 20 parts, of which the first appeared in 1887. The full Index, prepared by Dr. Pazschke, forms an additional part. The number of species described is 6023, the last of the series being the American *Dermatea acericola*, which has lately been found in Saxony and Switzerland. The work of Dr. Rehm shows a vast amount of labor and erudition, involving the examination of authentic specimens of Discomycetes from all parts of the world. The different volumes of the *Kryptogamen-Flora*, although all valuable, vary very much in the method of presentation of the subject. In some, especially that on higher cryptogams, there is such an excess of details that the reader is embarrassed rather than helped thereby. Dr. Rehm has arranged his material admirably. The descriptions are clear, neither too condensed nor too diffuse, and the copious notes are especially valuable to American mycologists since they contain references to American species related to those of Europe. The limits of genera are drawn less easily in Discomycetes than in some other orders of fungi, and the difficulty was all the greater in the present case, because a considerable number of species formerly generally placed in lichens, but in reality having no gonidia, have been regarded by Dr. Rehm as fungi and incorporated with other Discomycetes. W. G. F.

11. *Phycotheca Boreali-Americana;* by F. S. Collins, Isaac Holden and W. A. Setchell.—The fourth fascicle of this valuable series has recently been issued and maintains the excellent character of the earlier numbers. The striking feature of the present fascicle is the considerable number of species of Batrachospermum represented by very well-prepared specimens. Among the interesting Nostochineæ distributed are *Rivularia Bornetiana* and *Arthrospira Gomontiana* recently described by Setchell. W. G. F.

III. Miscellaneous Scientific Intelligence.

1. *National Academy of Sciences.*—The following is a list of the papers presented for reading at the meeting of the National Academy held in Washington, April 20–25.

E. W. Hilgard: The geological efficacy of alkali carbonate solutions.

M. Carey Lea: On the color relations of atoms, ions, and molecules.

E. D. Cope: On the characters of the Otocœlidæ.

A. M. Mayer: Exhibition of a linkage whose motion shows the laws of refraction of light. Location in Paris of the dwelling of Malus, in which he made the discovery of the polarization of light by reflection. (1) On experiments showing that the X-Rays cannot be polarized by passing through herapathite; (2) the density of herapathite; (3) formulæ of transmission of the X-Rays through glass, tourmaline, and herapathite.

W. A. ROGERS and FREDERICK BROWN: On the X-Rays from a statical current produced by a rapidly revolving leather belt.

G. W. HILL: Biographical memoir of James Edward Oliver.

C. H. DAVIS: Biographical memoir of Charles Henry Davis.

C. A. WHITE: Biographical memoir of George Engelmann.

T. C. MENDENHALL: Legislation relating to standards.

E. W. MORLEY and W. A. ROGERS: On the determination of the coefficient of expansion of Jessop's steel, between the limits of 0° and 64° C., by the interferential method. On the separate measurement, by the interferential method, of the heating effect of pure radiations and of an envelope of heated air.

C. S. PEIRCE: On the logic of quantity.

J. W. POWELL: Judgment in sensation and perception.

A. W. PECKHAM: The variability in fermenting power of the colon bacillus under different conditions.

O. N. ROOD: Experiments on the reflections of the Röntgen rays.

H. A. ROWLAND: Notes on Röntgen rays.

IRA REMSEN: Some studies in chemical equilibrium. The decomposition of diazo-compounds by alcohol. On double halides containing organic bases.

T. J. J. SEE: Results of researches of forty binary stars.

A. E. VERRILL: On a remarkable new family of deep-sea Cephalopoda and its bearing on molluscan morphology. The question of the molluscan Archetype, or Archi-mollusk. On some points in the morphology and phylogeny of the Gastropoda.

A. A. MICHELSON and S. W. STRATTON: Source of X-Rays.

A. W. WRIGHT: The relative permeability of magnesium and aluminum to the Röntgen rays.

C. BARUS: The state of carbon dioxide at the critical temperature. The motion of a submerged thread of mercury. On a method of obtaining variable capillary apertures of specified diameter.

C. S. HASTINGS: On a new type of telescope free from secondary color.

W. K. BROOKS: The Olindiadæ and other Medusæ.

W. K. BROOKS and GEORGE LEFEVRE: Budding in Perophora.

W. K. BROOKS and GILMAN DREW: Anatomy of Yoldia.

O. C. MARSH: On the *Pithecanthropus erectus* from the Tertiary of Java.

2. *New England Meteorological Society.*—A circular from the Secretary, WM. M. DAVIS, bears the information that at the last, thirty-sixth, regular meeting held in Boston on the 25th of April, the Society dissolved by vote of its members. The undistributed copies of the Society's investigations were presented to the Astronomical Observatory of Harvard College, subject to the disposal of the Director of the Observatory, who will hereafter receive all publications addressed to the Society.

OBITUARY.

DR. CARL NICOLAUS ADALBERT KRUEGER, Director of the Observatory at Kiel and editor of the latest forty volumes of the *Astronomische Nachrichten*, died at Kiel, April 21st, in the 64th year of his age.

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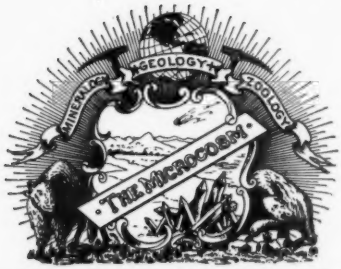

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